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ABSTRACT

This final report describes the activities and accomplishments of a 3-year study on the compensatory effectiveness of three assistive technologies, optical character recognition, speech synthesis, and speech recognition, on postsecondary students (N=140) with learning disabilities. These technologies were investigated relative to: (1) immediate compensatory effects on reading comprehension, proofreading and written composition; (2) long-term effects on academic retention and success; (3) long-term effects on academic behaviors and attitudes; and (4) cost effectiveness in relation to other compensatory strategies. Results indicated that all three of the technologies significantly alleviated difficulties in reading comprehension, proofreading and written composition; significantly improved long-term academic retention and success; positively influenced academic behaviors and attitudes; and were highly cost effective as compared to other compensatory interventions. The most dramatic findings were in the area of retention. Participants in the study had a drop-out rate of 1.4 percent as compared to 34 percent for matched controls over the same 3-year period. Individual sections of the report present an overview of the project, and detail the project's purpose, background and origins, specific studies conducted, and evaluation/project results. Extensive appendices include the text of five publications related to the study's findings, a questionnaire/interview schedule, course outlines, and sample lesson plans. Contains over 100 references. (DB)

`An Investigation of the Compensatory Effectiveness of Assistive Technology on Postsecondary Students with Learning Disabilities. Final Report.

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A. **Cover Sheet**

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FIPSE Program Officer:	Dave Johnson
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B. <u>Summaries</u>

1. Paragraph Summarizing the Project

The study investigated the compensatory effectiveness of three assistive technologies on postsecondary students with learning disabilities: optical character recognition, speech synthesis and speech recognition. These technologies were investigated relative to their (1) immediate compensatory effects on reading comprehension, proofreading and written composition; (2) long-term effects on academic retention and success; (3) long-term effects on academic behaviors and attitudes: and (4) cost effectiveness in relation to other compensatory strategies. Results indicated that all three of the technologies significantly alleviated difficulties in reading comprehension, proofreading and written composition, significantly improved long-term academic retention and success, positively influenced academic behaviors and attitudes and was highly cost effective as compared to other compensatory interventions.

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An Investigation of the Compensatory Effectiveness of Assistive Technology on Postsecondary Students with Learning Disabilities: Final Report

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A. Project Overview

The project was a three-year grant to invesitgate the compensatory effectiveness of three promising technologies for postsecondary students with learning disabilities: optical character recognition, speech synthesis and speech recognition.[1] The immediate effects of the technologies on reading comprehension, proofreading and written composition were investigated during the first year in three separate studies involving eighty students. All three technologies were found to be effective in assisting students to circumvent their academic difficulties. In years two and three information was gathered on long range effects on academic retention and success, academic behaviors and attitudes and cost effectiveness. Also in years two and three, sixty more students were trained on the equipment with an emphasis on enhancing writing skills, a salient need of the learning disabled population. Measures of retention and success, changes in academic behavior and attitudes and cost effectiveness all indicated positive benefits from the use of the three technologies and in assistive technology as a general compensatory strategy.

B. Purpose

Postsecondary students with learning disabilities constitute the fastest growing population of students with disabilities on campuses nationwide. Although such students can exhibit a variety of academic problems, reading and writing deficits are the most frequently reported difficulties. One approach to alleviating their difficulties that has received recent attention is assistive technology, mechanical or electronic devices designed to enhance performance or circumvent the disability altogether. Three emerging technologies which appeared to hold great promise for enhancing reading and writing performance were optical character recognition, speech synthesis and speech recognition. The study investigated the technologies with regard to: (1) immediate compensatory effect on reading and writing; (2) effect as compared to personnel-intensive strategies such as human readers and transcribers; (3) long-term effect on retention and success; (4) effect on academic behaviors and attitudes; and (5) cost effectiveness.

C. Background and Origins

In 1985, the Office of Disabled Students Services established the Learning Disabilities Program to encourage the success of the expanding population of learning disabled students, which has grown from 55 students to over 350 at present. In 1988, the Computer Access Laboratory was founded through the Office to provide computer access for students with disabilities, including learning disabilities. Experts in assistive technology and in learning disabilities soon began a number of collaborative projects involving assistive technology. Experimentation with optical character recognition, speech synthesis and speech recognition indicated that these technologies were helpful to students with difficulties in reading and written composition. Yet little formal research could be found in the literature regarding the use assistive technology with postsecondary students with learning disabilities or on the three technologies in question. Because of the central role the Office of Disabled Student Services had played nationally and internationally in the development of assistive technology for persons with disabilities, the staff believed the Office was in a unique position to both conduct needed controlled research on these technologies with postsecondary students with learning disabilities and to disseminate the findings broadly.

D. Project Descriptions

Immediate Compensatory Effectiveness--During the first year, three controlled studies were conducted as follows:

1. <u>Optical Character Recognition and Reading Comprehension</u>: Students read the Formal Reading

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[1] Optical character recognition scans text from various sources, such as handouts, textbooks, and converts it to a computer document; speech synthesis/screen review then reads the computer document aloud using a synthesized "voice" while simultaneously highlighting the text. Speech recognition converts words spoken into a headphone-mounted microphone into text on the computer screen.

Inventory, a series of successively more difficult paragraphs followed by comprehension questions, under the following conditions: (1) silently, with no assistance: (2) having a human reader read the selection aloud; and (3) using optical character recognition in conjunction with speech synthesis to scan and read the passages and questions.

2. Speech Synthesis/Screen Review and Proofreading: Students wrote the first draft of an expository essay, then proofread their essay with each third being read under a different condition: (1) with no assistance: (2) having the section read aloud by a human reader; and (3) using speech synthesis/screen review.

3. Speech Recognition and Written Composition: Students wrote three 500-word essays under the following conditions: (1) using speech recognition; (2) dictating the essay to a transcriber; and (3) with no assistance. The essays were given a holistic score by past readers of the Upper Division Written Proficiency Examination. Linguistic analysis included twenty-two measures of fluency, vocabulary and syntax which were later subjected to statistical analysis.

Long-Term Effectiveness--During years two and three information was gathered on indicators of academic outcomes including grades, grades in academic courses, withdrawals, drop-outs, graduation rates, make-ups, and passage rates on the Upper Division Written Proficiency Examination. A matched group of students with learning disabilities who did not receive training was identified; each student in the study was paired with a match who had begun during the same semester as the partcipant and the progress of the pairs was plotted. Participants were given a pre and post-study questionnaire/interview on the use of campus services, computer use, compensatory strategies and study habits (See Appendix C). The questionnaire responses were supplemented by information taken from data bases kept by the Office on use of services, logon records from the Computer Lab and a variety of University and system-wide data bases.

Other activities in year two and three included the training of sixty more students on the equipment, utilizing a "mini-course" format which emphased enhancing written language with the use of assistive technology (See Appendix D for course outlines). A systematic method of linking diagnotic information to a prescription of specific technologies was developed in collaboration with the two Learning Disabilities Specialists. Finally, a cost analysis was conducted which compared costs of purchasing, training and maintaining the technologies to hiring and training personnel to provide comparable services.

E. Evaluation/Project Results

Immediate Compensatory Effectiveness--

1. Optical Character Recognition/Speech Synthesis and Reading Comprehension: Means across conditions did not show a significant differences because the technology enhanced the performance of students with marked deficits, but interfered with the comprehension of more proficient readers. However, a significant correlation ($p > .001$) was found between silent reading score and improvement under the technology condition such that **the greater the disability, the more the technology enhanced performance.**

2. Speech Synthesis/Screen Review and Proofreading Efficiency: **Students found more errors overall using the technology** than when listening to a human reader or without assistance. Additionally, more errors were found under the technology condition for seven of the nine categories of errors, four at a significant level ($p > .00005$).

3. Speech Recognition and Written Composition: Significantly more students received **higher holistic scores** under the technology condition than when writing without assistance ($p > .05$). When compared to their non-disabled peers, the distribution of scores of the learning disabled participants was significantly inferior to the non-disabled students under the "no assistance" and "transcriber" condition, but when writing their essays using speech recognition, the learning disabled **did not differ significantly from their non-disabled peers.** Linguistic analysis of the essays indicated that those

written using speech recognition used a higher percentage of "long words" (words of 7 or more letters) and that this measure was highly predictive of holistic score. The investigators concluded that the technology "encouraged" the use of students' stronger oral vocabulary by circumventing spelling and punctuation difficulties and, because the technology recognized longer words better than short ones, counteracted a tendency to chose immature vocabulary.

Long-Term Effectiveness--The most dramatic findings of the study were in the area of retention. Participants in the study had a drop-out rate of 1.4% as compared to 34% for the matched controls over the same three-year period, and 48% for the non-disabled population over four years. Graduation rates and make-up rates rose significantly for the participants and also differed significantly from that of matched subjects, further attesting to the participants' greater "persistence" at completing their curricula. Grades in academic courses showed significant increases (although these did not influence overall GPA enough to reach significance). Passage rates on the Upper Division Written Proficiency Examination showed remarkable improvement. There was a 95% passage rate for participants as compared to 48 % previous to the study, 52% for the matched group, and 75% for the non-disabled population.

Other researchers have noted that acceptance of the learning disability, greater self-advocacy, self-esteem, self-reliance and greater use of technology tend to co-vary, and to be associated with "success." A pattern became evident of participants acquiring many of the above behaviors over the three year period. There was a decrease in the use of services over the three-year period, and an increase in independence (e.g., relying less on friends and family for assistance). Accompanying this independence were signs of increased understanding and acceptance of their disability as measured by content analysis of questionnaire responses and supplemented by a standardized measure of alienation, academic leadership, interest and independence. The participants frequently attributed their positive upswing directly to greater use of the computer.

Cost Effectiveness--A "bare bones" estimate based on purchase, training and maintenance of the technologies was prepared, as well as a "moderately enhanced" estimate which included some outreach, needs assessment and provision for further training based on the needs assessment. These estimates were adjusted to accommodate the findings from the study as to increases in computer use and other services. The two estimates were then measured against the cost of recruiting, employing and training personnel to provide comparable services (transcribers, proctors, etc.). The "bare bones" cost savings to the Office of Disabled Student Services and the University was $310 per student, per semester, and $234 for the "moderately enhanced" services.

Dissemination--The study yielded six publications (in various stages of preparation and submittal) in major refereed journals in learning disabilites and four papers have appeared in proceedings of the Annual Technology for Persons with Learning Disabilities Conference Proceedings sponsored by California State University, Northridge CENTER ON DISABILITIES. There were also fourteen presentations at various national and international professional conferences. On-campus activities included three national and international workshops sponsored by the CENTER ON DISABILITIES, and numerous presentations to specific academic departments and student services units (See Appendix A for publications and presentations).

F. Summary and Conclusions

The findings on the immediate compensatory effectiveness of the three technologies were on the whole positive, but indicated that not all students were helped by the technology initially, nor was the technology equally helpful for all tasks. Therefore the researchers recommend that a careful examination of a student's academic strengths and weakness (supplemented by formal and informal measures of performance using the technology on various tasks) be linked to the prescription of specific technology. Secondly, through their experiences with training postsecondary students on these emerging technologies, it was evident that the population requires the adjustment of training methods from those employed for other disabled and non-disabled populations on computer technology (e.g., use of one-on-one training, limiting instruction to compensatory rather than remedial purposes, more frequent refresher sessions, etc.). Third, the population has a specific need to increase the use of computers to enhance written composition skills. Fourth, although machines can never fully "replace" people, the three technologies did tend to outperform human helpers on specific academic tasks. Technology was also more cost effective, and had the added advantage of increasing the independence of the participants. Fifth, long-term improvements in academic outcomes, behaviors and attitudes can be expected with the use of assistive technology, and frequently began a positive upswing in academic performance, self-esteem and the ultimate "success" of many of the participants.

G. Appendices:

(1) What forms of assistance from FIPSE were helpful to you? How can FIPSE more effectively work with projects?

The written materials and guidelines were helpful in organizing interim reports and renewals, and later, in refocusing the efforts of the study to maintain overall continuity. They suggested that projects often take unexpected turns which allowed the current researchers to pursue a fruitful line of inquiry. For example, the researchers were spurred to conduct further data analysis when it was discovered that the essays being gathered were unique in the literature as to both length and complexity of the compositions. This allowed the authors to make a substantial contribution to the field of learning disabilities which would not otherwise have been possible. The FIPSE staff was generous in fostering a policy of exploration which allowed for the study to take advantage of such serendipitous circumstances. Additionally, it was greatly appreciated by the investigators that the site visits were permitted to be flexible so that the context in which the study was conducted could be realistically represented and hence the full impact of the findings understood.

(2) What should the FIPSE staff consider in reviewing future proposals in your area of interest? What are emerging new directions? What are key considerations, given your type of project?

First, the single variable which ensured the success of this longitudinal study, despite flooding, the most destructive civil disturbance of the century, a major fire, on the heels of which came a devastating earthquake which damaged all 53 buildings of the campus,[6] was the support of the administration, staff and disabled students from the Office of Disabled Students Services, the Computer Access Laboratory, and the CENTER ON DISABILITIES. The sense of the project being a community effort and the cross-pollination which was fostered not only by the geographic proximity of specialists from various disciplines and perspectives, and students with a variety of disabilities who unselfishly offered information and insight, but by the environment of mutual respect for service providers and recipients, for researchers as well as "front-line" clinicians, would not permit the investigators to merely fulfill the obligations of the grant, but rather spurred the project to accomplish goals not yet conceived at the beginning of the study. Hyperbole aside, the context within which longitudinal research takes place must have the full support of those involved. Maintaining contact with participants over a three-year period is difficult even under the best of circumstances and requires the cooperation of all members of the study community.

Second, the project focused on technology, a rapidly-changing area by its very nature, rendering it somewhat like a frontier town. There is the potential for great advances in a short period of time, the "boom town." But also, there is possibility of the rapid abandonment of a line of development, usually based on material rather than social considerations, the equivalent of the "ghost town." I would hope that FIPSE will consider the findings of this study as an encouragement to support the three technologies studied in future grants and to support studies involving the use of other assistive technology for persons with learning disabilities so that the social benefits to this population will not become a "ghost town" due to the lack of material

[6] We managed to complete the study before the advance of the killer bees had reached us.

support. Unfortunately, frontier towns can also be lawless; they follow the dollar rather than the church bell. Specifically, although the policy of the Department in the past may have been to limit purchases of materials such as computers directly by the institutions it favors, often for the valid reason that the personnel to maintain and tailor the equipment to the needs of the setting are lacking, the investigators would suggest that the field as a whole, perhaps the culture as a whole, has now reached a point of saturation with such expertise that the problems of misuse or non-use will not be a threat to the success of future projects. The investigators would urge FIPSE, therefore, to offer greater and more direct budgetary support for material purchases of assistive technology.

C. Body of the Report

A. Project Overview

Students with learning disabilities are the fastest growing group of disabled students on college campuses. The rising number of students requesting assistance from the Office of Disabled Student Services at California State University, Northridge, as well as at most other postsecondary institutions throughout the nation, has necessitated the development of strategies to ensure their academic retention and success. One such approach which has gained increasing attention over the last several years is assistive technology. Three promising technologies seemed especially suitable for use with students with learning disabilities: optical character recognition in conjunction with speech synthesis, speech synthesis/screen review and speech recognition. Although many encouraging testimonials had been circulating throughout the computer and educational literature, little controlled research had been conducted to evaluate the compensatory effectiveness of these technologies for postsecondary students. The project began as an attempt to formally investigate the effects of these three promising technologies: (1) in assisting students with learning disabilities to compensate for their immediate difficulties in reading comprehension, proofreading and written composition; (2) to compare the effects of the technologies to the more personnel-intensive strategies currently being used such as readers, transcribers, note-takers, proctors, etc.; (3) to assess the long-term effects on academic retention and success; (4) to describe changes in academic behaviors and attitudes (if any); and (5) to assess the cost effectiveness of the technologies as compared to the more traditional strategies being employed.

During year one, eighty students were first trained on the equipment, then evaluated as to the immediate compensatory effectiveness of the technologies as compared to receiving no assistance and to receiving traditional strategies such as readers and transcribers. In years two and three the long-term effects on academic retention and success were measured. Also in years two and three, since all three technologies proved to be effective interventions, sixty more postsecondary students with learning disabilities were trained on the equipment with particular emphasis on improving writing skills, the academic need identified by both students and staff as being the most salient for the population. Finally, in year three a cost analysis was prepared to determine the relative expenditures necessary for the purchase of and training on the technologies as compared to training and employing personnel to carry out comparable services using traditional strategies. A "bare bones" cost analysis was done as well as one that included modest outreach, needs assessment and training on the three technologies.

Results on the immediate compensatory effectiveness of the technologies indicated that optical character recognition in conjunction with speech synthesis was significantly effective with students showing marked deficits in reading comprehension, speech synthesis/screen review significantly improved proofreading efficiency and speech recognition significantly enhanced holistic scores on written compositions for postsecondary students with learning disabilities.

Several long-term measures of academic success showed marked and significant improvement. Grades in classes with heavy reading and/or writing requirements showed significant improvement. The most striking findings were in the area of retention rates; only two students left school or were disqualified out of the 140 participants over the three-year period, which was highly significant as compared to both non-disabled students and to a matched group of postsecondary students with learning disabilities who did not receive training on the technology.

Other significant findings included: (1) significantly higher rates than the matched group of repeating incomplete courses for a satisfactory grade; and (2) a significantly higher rate of passage of the written composition "exit" exam, as compared to learning disabled populations in previous years, to the matched group for the same three-year period, and even to the passage rate for non-disabled students.

Although comparative data was not available for the matched group or for non-disabled conrols, several changes were evident from pre and post questionnaire responses of the participants regarding academic behaviors and attitudes: there was a 78% increase in the use of assistive technology in the trained group; there was strong evidence that students generalized the use of technology to purposes other than reaidng and writing within the academic setting; there was equally strong evidence that they applied what they had learned to employment, social and arecreational settings outside the University; there was an overall drop in the use of services both within the Office of Disabled Student Services and from other departments and agencies on campus; there was an overall drop in the reliance upon friends, classmates, family and fellow employees for assistance with reading and writing tasks. Finally, a standardized measure of academic attitudes revealed significant changes in feelings of alienation, in leadership and initiative, and in academic interest.

The cost analysis revealed that the expenditures necessary for the technological intervention as opposed to those required for the training and employing of personnel to accomplish equivalent services, were less for both a "bare bones" estimate and for a modest "enhanced services" estimate. Savings were $310 and $234, respectively, per student, per semester, given current demands and salary schedules.

B. Purpose

The study addressed the problem of determining the efficacy of utilizing assistive technology as a compensatory strategy for postsecondary students with learning disabilities to ensure their academic retention and success. The population of persons with learning disabilities seeking support services at colleges and universities has been consistently growing at rapid rates throughout the nation (American Council on Education, HEATH Resource Center, 1992). The phenomenal growth in demand for services is partially explained by the fact that it has only recently become evident from the literature on persons with learning disabilities that despite substantial efforts to remediate the specific deficits exhibited at the primary and secondary levels, difficulties persist into adulthood for many, if not most persons with learning disabilities (See, for example, *Learning Disability Quarterly*, Summer, 1993, a special issue on adults with learning disabilities). Additionally, many adults with milder learning disabilities or with superior intellectual capacities do not experience severe difficulties until challenged by the more rigorous university curriculum. Hence, these students are either not identified or do not seek assistance until they reach the postsecondary setting, but have further added to the demand for services than would be projected from secondary and primary learning disabled population estimates.

The specific types of academic problems most frequently experienced by postsecondary students with learning disabilities are in the areas of reading comprehension and written language, and to a somewhat lesser extent in mathematics, memory, attentional or organizational domains (Cordoni, 1979; Vogel, 1987). The types of assistance that has been provided by the Office of Disabled Students Services at California State University, Northridge, as well as at many other postsecondary institutions, have been largely compensatory rather than remedial in focus. These strategies, aimed at circumventing rather than remediating the problems experienced by postsecondary students with learning disabilities, have included diagnostic evaluation, providing testing accommodations such as granting more time for taking exams in an alternative, private, proctored setting, the use of human readers, transcribers and notetakers, and to a lesser extent, tutors in specific subject areas, proofreading and editing assistance, and personal counselling. The compensatory approach has arisen quite naturally in offices of disabled student services at the university level, given that many of the strategies described here were already being employed to work around other types of disabilities such as visual, motor or communication deficits long before they were applied to persons with learning disabilities.

But apart from the fact that compensatory strategies have been successful in assisting students with other types of disabilities, there is sound rationale for choosing such an approach for persons with learning disabilities. First, as noted above, remedial efforts in the past have not been entirely successful. Second, many students suffer from remedial "burnout," i.e., the continual focus in the past on their areas of deficit and the extended use of tedious drill and practice threatens to destroy not only self-esteem but the very core of the learning disabled student's ability to enjoy the learning process. Such students can become damaged and discouraged to such an extent that the very desire to continue their education is called into question. Third, there are frequently practical time considerations that preclude a remedial approach. A student may have no more than a week to read several chapters of a book, or to research and compose a critical essay. There simply is not enough time for an elaborate phonics program or structured spelling curriculum to be planned and executed, which even if successful, may or may not, in the end, alleviate <u>all</u> the students difficulties. There is also the problem of either locating or training personnel in the specialized field of learning disabilities in time to be of service to the student.

With the strain on campus agencies from the increasing number of learning disabled students and from recent federal mandates such as The Rehabilitation Act of 1973 (P.L. 92-112) and The Americans With Disabilities Act (P.L. 101-336), not to mention shrinking federal and state financial resources, offices of disabled student services have begun to explore alternatives to the personnel-intensive strategies currently being used to ensure the academic success of postsecondary students with learning disabilities. One such strategy that has gained attention recently is assistive technology, the use of various mechanical and electronic devices to enhance performance. These might include variable speed tape recorders, recorded books, high-frequency listening devices, talking calculators, hand-held computerized dictionaries, word processors, optical character readers, lap-top computers, data organizers, grammar and spell-checking computer programs, word prediction programs, and specialized computer keyboards. The devices may be used to augment performance or to circumvent the disability altogether.

Three assistive technologies seemed especially promising candidates for use by students with learning disabilities: (1) optical character recognition which converts text to a computer document then reads the text aloud to students, when combined with speech synthesis; (2) speech synthesis/screen review which reads text aloud while simultaneously highligting the words on the computer screen; and (3) speech recognition which allows the user to dictate sentences, word-by-word into a headset-mounted microphone, and have them converted to text on the computer screen, relatively free of spelling and punctuation errors.

The Office of Disabled Students Services was able to acquire the above technologies for the Computer Access Lab, and early experimentation by students with learning disabilities were highly encouraging as to their usefulness. But, as mentioned earlier, very little in the way of research regarding the use of assistive technology with postsecondary students with learning disabilities had been conducted. What little could be found by the present investigators was limited to research on word processing only (Brown, 1987), or was clinically descriptive and anecdotal, rather than experimental in design. Further, there was virtually no research on the three very promising technologies described above. The investigators were anxious to conduct research whose findings would be highly reliable, valid and appropriate for wide dissemination in professional as well as practical formats.

The researchers framed the following questions for investigation: (1) Do optical character recognition in conjunction with speech synthesis, speech synthesis/screen review and speech recognition better alleviate the immediate reading comprehension, proofreading and written composition difficulties of postsecondary students with learning disabilities as compared to receiving no assistance or traditional, personnel-intensive interventions? (2) Does the use of the three technologies by postsecondary students with learning disabilities promote retention and academic success over the long-term? (3) Do the academic behaviors and attitudes of postsecondary students with learning disabilities show any positive changes over the long-term (e.g., reduced use of support services, independence from informal modes of assistance, less study time, improved self-esteem, etc.)? (4) Are the technologies cost effective as compared to the more traditional, personnel-intensive interventions (e.g., readers, transcribers)?

C. Background and Origins

In 1985 the Office of Disabled Students Services at California State University, Northridge obtained a grant from the California State Department of Rehabilitation to establish a program for postsecondary students with learning disabilities. An administrator and two specialists in learning disabilities organized a program of services which included diagnosis and assessment, academic and career counselling, the provision of testing accommodations, counselling and instruction in compensatory strategies, the provision of readers, notetakers, transcribers and proofreaders, and training on the use of a few "low tech" technological devices such as hand-held spell checkers, talking calculators, and variable speed tape recorders. The program for students with learning disabilities has grown from an initial enrollment of 55 students in 1985 to over 350 at present and now represent nearly half of the population of students eligible for services through the Office of Disabled Students Services.

In March of 1988, under a separate Department of Rehabilitation grant, a Computer Access Laboratory was established in the Office of Disabled Students Services to train students with disabilities, including those with learning disabilities, in an effort to increase students' academic retention and success and promote transition to employment. For the first time, professionals from the field of learning disabilities were brought together with experts in assistive technology, and service providers from both fields began to see many possibilities for assistive technology to be applied to the postsecondary learning disabled population. Since the initiation of the Lab, learning disabled students were trained to use word processors as well as laptop and desktop computers. An ever-increasing portfolio of software programs designed either for non-disabled or for other types of disabilities, were found by the students and staff to enhance the performance of postsecondary students with learning disabilities. Three developing technologies appeared to hold great potential for assisting students with learning disabilities, which are described below:

(1) **Optical character recognition in conjunction with speech synthesis.** An optical character recognition system scans text materials in various fonts and formats (e.g., chapter from a book, newspaper article) and creates a word processing document which can then be "read" back aloud using a speech synthesis system. As mentioned previously, one of the most frequently reported difficulties for students with learning disabilities is in the area of reading comprehension. Research on the nature of the reading problems of students with learning disabilities indicates that difficulties with the decoding process are responsible for the comprehension deficits experienced by many learning disabled students (Perfetti, 1975; Lundberg & Leong, 1986; Swanson, 1992). A speech synthesis/screen review system would allow students with such difficulties to resolve comprehension problems by converting the text to auditory input, thus circumventing the decoding process altogether.

(2) **Speech synthesis/screen review.** This type of system, the only computer technology especially developed for persons with learning disabilities, reads text from a computer document out loud, while simultaneously highlighting the text on the screen. There is evidence, again from the literature on persons with learning disabilities, that a multisensory presentation of written material could assist students not only in the reading task, but in proofreading their work by alerting them to errors in both the visual and auditory modalities (Fernald, 1943; Gillingham & Stillman, 1968; Heckleman, 1969; and more recently, Myers & Hammill, 1982).

(3) **Speech recognition.** The user of such a system dictates sentences word-by-word into a microphone while the program converts the phonetic input into text which appears on the screen with a high degree of accuracy in both spelling and punctuation. Many students with learning disabilities experience great difficulties with written language and spelling, while their oral language abilities may remain relatively in tact (Howell, 1956; King & Rental, 1981; Myklebust, 1973; Wilson, 1963). Such a system allows the student to utilize these stronger oral language processes by generating written text which is essentially free of the frequent spelling and mechanical errors which typify the writing of many learning disabled persons.

D. Project Descriptions

Immediate Compensatory Effectiveness

During year one the major task of the researchers was to discover whether the technologies would provide immediate compensatory assistance for students with learning disabilities. Three formal studies were set up to answer the following three questions: (1) Does optical character recognition in conjunction with speech synthesis improve the reading comprehension scores of postsecondary students with learning disabilities as compared to receiving no assistance or receiving the traditional intervention of being read aloud to by a human reader? (2) Does speech synthesis/screen review improve the proofreading efficiency of postsecondary students with learning disabilities checking their own compositions as compared to receiving no assistance or having them read aloud by a human reader? (3) Does speech recognition improve the holistic scores on the written compositions of postsecondary students with learning disabilities as compared to receiving no assistance or dictating the compositions to a transcriber?

A "recruitment" letter was prepared to entice students to come in to the Compter Access

Laboratory to receive training on this "cutting edge" technology, and offered a further incentive of $6 per hour for participation in one or more of the three formal studies. The letter was sent to all 350 students with learning disabilities registered with the Office of Disabled Students Services. The Learning Disabilities Specialists also referred incoming and newly-identified students with difficulties in reading and/or written language.

During the first appointment with an investigator, students were given a brief description of the intent of each study, permissions were obtained and student records were examined to verify that each participant did in fact have a disability in the area designated for the study in which he or she wished to participate. Also during the first hour the pretest questionnaire was administered. Areas of inquiry included use of services with the Office of Disabled Students Services and from other campus service offices, study habits, use of informal compensatory strategies and social networks for assistance and the use of computers and other technology in various life settings such as work, school, social and family environments. The next appointment was set up to begin testing and/or training on the appropriate technology.

A description of the methodology employed in the three studies now follows:

1. <u>Optical Character Recognition/Speech Synthesis and Reading Comprehension</u>

The silent reading portion of the Formal Reading Inventory was selected to assess reading comprehension. It consists of thirteen short readings, each followed by five comprehension questions. The readings become increasingly difficult and more complex syntactically and semanatically as the student progresses. The investigator first establishes a baseline paragraph on which the student answers all five comprehension questions correctly. The student then reads through successive selections until three or more questions are missed. The students took the test under the following three conditions: (1) reading the exam and questions silently with no assistance (NA); (2) having the selections and questions read aloud by a human reader (RA); and (3) using optical character recognition in conjunction with speech synthesis to scan in and read the selections (SS).

The order in which the conditions were administered were randomly assigned.[1] There were four forms of the Formal Reading Inventory (A, B, C, and D), all of which contained different reading selections, which were also randomly assigned for each administration of the test.

Training on the technology consisted of demonstrating the simple operation of the optical character recognition and speech synthesis programs then allowing the student to participate in guided practice using various types of written materials (pages from a bound volume, single pages of typed material, etc.) and allowing the student to adjust the speech synthesis program options such as visual display, pitch, volume and speed of presentation until the most comfortable selections were made. Average training and exploratory time was 48 minutes.

Under the optical character recognition/speech synthesis condition, students were given a few minutes in the Computer Access Laboratory to refresh their memory on the operation of the equipment and to adjust the speech synthesis program to fit their preferences. The test was then

[1] The six possible permutations of the order of conditions were NA-RA-SS, NA-SS-RA, RA-SS-NA, RA-NA-SS, SS-NA-RA and SS-RA-NA. A list of fifty permutations (without replacement) was generated using a table of random numbers. Each new participant was simply given the next permutation on the list.

given to the student and one of the investigators remained available in the Laboratory to handle any technical problems encountered and to establish the baseline and ceiling paragraphs. The students were allowed to go back to reread the paragraph if desired and no time limits were imposed. They were given the choice of using headphones or listening to the selection from the speaker attached to the computer.

Under the "no assistance" condition, the students read the selections silently in the private office of one of the investigators. Again, no time limit was imposed and students were allowed to look back at the paragraph when necessary. The investigator was present to establish the beginning paragraph and to terminate the exam when the student missed more than three reading comprehension questions.

Under the "read aloud" condition, one of the investigators read the paragraphs to the students in a private office. No time limits were enforced, and the investigator gave instructions to the students that any part of the selection or questions could be reread as many times as necessary. Thirty-seven students completed the administration of the exam under all three conditions and all were included in the analysis of results.

2. <u>Speech Synthesis/Screen Review and Proofreading Efficiency</u>

The task chosen for evaluating speech synthesis/screen review was to have students proofread a 500 word essay they had actually written. The researchers were interested in assessing the technology under as naturalistic a setting as possible. Although a few standardized tests contain a section designed to assess proofreading, the manner in which these tests are derived render them contextually quite different from the real-life proofreading situations in which students must actually perform. Typically, a well-constructed passage from a piece of literature is selected and a discrete number of errors is inserted into the text. First, these "perfect" passages, composed by veteran professional writers, are unlikely to resemble the real written language samples of inexperienced undergraduates and even less likely to reflect the writing that might be generated by students with a variety of learning disabilities. The sheer number of errors per essay in some cases would preclude comparability; the range of errors in the present sample was from as few as 20 to as many as 200 errors in a single essay. Second, the types of errors which are inserted into these passages are designed to test knowledge of specific rules of grammar, spelling, punctuation and the like. Therefore, they are usually clear-cut examples of rule violations which have a single, unambiguous, multiple choice "right answer." Real life errors, on the other hand, are frequently not nearly so clear cut as to which rule might apply and often have more than one solution for "fixing" the problem. Compare the two passages below, one from a standardized test and one from a students' essay:

(1) Betty lives on oak road. (Hammill & Larsen, 1978)

(2) DaD caME hoME LaTE LasT NIgHT And MoM GoT sick aND TiRED oF iT.

Third, the standards by which the above "naturalistic" sample may be judged would be expected to vary considerably if evaluated by a third grade teacher, a professor at a university, or an editor of a professional journal. While the professional editor would certainly disapprove of the cavalier use of upper and lower case, the third grade teacher may choose to ignore all capitalization difficulties, as well might a college professor accustomed to deciphering a variety of scribbled essay exams over the years. The point is that it was not known in advance by the researchers to what standard the students in the investigation would be held. The investigators, consequently, were just as interested in the types of errors that "counted" to the intended audience, the actual readers of students' work product, as they were in the discrete number of errors upon which editors, teachers and professors might agree for the purposes of constructing an "airtight" and reliable reading for a test item.

To determine the type of errors that "counted" for the university setting in which the study took place, a panel composed of the two researchers, a psychologist who is a specialist in learning disabilities responsible for assessment and identification of students with learning disabilities, and two graduate students from the English Composition Department who were readers for the Upper Division Written Proficiency Exam read several essays written by postsecondary students with learning disabilities. Each of the five panelists circled errors and indicated in the margin the nature of the error in a brief description (e.g., "needs quotation marks," "verb tense," "subject-verb agreement," "no cap," etc.). Nine categories of errors were identified by the panel, which were as follows: (1) capitalization; (2) punctuation; (3) spelling; (4) usage (denotative and connotative meaning errors, errors in use of figures of speech and idioms); (5) grammar/mechanical (subject/verb agreement, tense agreement, etc.); (6) grammar/global (sentence fragments and run-on sentences); (7) typographical; (8) content/organization (errors in sequencing of events, redundancy, incoherence, illogicality, etc.); (9) literary style (slang, mixed metaphor, weak analogy, inappropriate language, etc.).

Once the manner of determining the number and types of errors had been established, the researchers gathered the first draft compositions from the participants, 34 postsecondary students with a learning disability in the area of written language. The first appointment with participants was devoted to the writing task (with a few students taking more than one session to complete their 500-word essay). Students could either handwrite or type their essays directly into the computer, and were given the instruction not to correct errors. Once the essays were written, the handwritten essays were transcribed as a computer document, then each of the essays was divided into three parts.

During the second session the student proofread his or her entire essay with each of the sections being read under a different condition: (1) with no assistance (NA); (2) having a human reader read the essay aloud, sentence by sentence (RA); and (3) using speech synthesis/screen review (SS). The order of the conditions was randomly assigned (without replacement) so that each condition would be equally represented, as in the previously-described study. Students were given the instruction to correct or circle errors they found in spelling, punctuation, etc., as well as any problems with sentences or content by adding or changing a word or two, but not to cross out whole sentences or paragraphs and rewrite them.[3]

Each of the essays was then scored for total number of errors and category of each error by four readers--one of the researchers, one specialist in learning disabilities, and two English Composition graduate students. Interrater reliability for total number of errors was .93 and for category placement was .96. Finally, errors found by students were counted. An error was judged "found" if it was either circled or successfully corrected (i.e., a correction which did not remove or alleviate the problem was not counted as a "found" error). Thirty-four students generated a first draft and returned for the second session to proofread them.

[3] This was done so that a whole new set of errors would not be generated, necessitating another proofreading session by some, but not all, of the participants.

generated a first draft and returned for the second session to proofread them.

3. Speech Recognition and Written Composition

The task selected to assess written composition skills was a "mock" Upper Division Written Proficiency Examination, a timed, holistically scored essay exam of approximately 500 words, which is taken by juniors and seniors some time before graduation. Students are given an assigned topic and must organize and write the essay within an hour. Again, the researchers were interested in assessing the technology in as naturalistic a setting as possible, so every effort was made to emulate the conditions under which the real Written Proficiency Exam was administered. Participants in the study were given instructions identical to those on the actual exam and old test questions were employed to ensure comparability of the task. One of six possible questions was randomly assigned to each administration of the exam. The only deviation was that participants in the study were given extra time (up to one hour) which is the standard accommodation given to students with learning disabilities by the University.

Students composed three compositions under the following conditions: (1) with no assistance (either handwritten or on a word processing program without spell checking the document) (NA); (2) dictating the essay to a transcriber who would handwrite the essay; and (3) using a speech recognition system (without spell checking). Since the training on the speech recognition program involved between five and ten hours, the researchers suspected a training effect might occur. To assess such a possible effect, students were placed in one of two experimental groups. Group A first received training on the speech recognition program, then took all three essay exams (i.e., one with speech recognition, one using a transcriber and one with no assistance). Those in Group B first took two of the exams under the "no assistance" and "transcribed" conditions, then received training and took the final exam using the speech recognition equipment. Since a practice effect, as well as a training effect was possible, the order in which the exams were administered was randomly assigned and the size of Group A and B were counterbalanced so that no condition received an advantage due to position.

Use of Equipment and Training Procedures: Speech recognition systems were originally used in the Computer Access Laboratory at CSUN as assistive technology for other disabled populations such as persons with profound motor impairment and/or communicative disorders. These populations use speech exclusively to activate all commands and vocabulary corrections required for operation. During the process of training themselves, however, it was discovered that persons without severe motor impairment could comfortably switch from using voice commands to using the keyboard to execute many routine operations. This was especially helpful in correcting errors the system made in "guessing" the word just spoken. The procedure for correcting such an error using voice commands exclusively involves spelling out the word orally, using the International Communications Alphabet ("alpha, bravo," etc.). This was a highly tedious and distracting procedure for the researchers and was expected to be even more so for a person with a learning disability. Fortunately, the alternative of simply striking the first letter of the desired word on the keyboard frequently resulted in the correct word choice being generated. This was a tremendous help in shortening training time.

A training program was developed wherein the researcher spent one hour introducing the student to basic operations and entering a small set of 100 commands. During the second hour of training, the student was instructed on how to correct inaccurate guesses made by the program.

Both the "alpha-bravo" method and the keyboard method were taught and students were given the choice of using either procedure from that point on. All consistently chose the keyboard method of correction. The next training sessions were devoted to practice dictation to allow the system to adjust to the phonetic qualities of the individual student. A researcher sat next to the speaker to monitor many students' tendency to pass over wrong word choices made by the system. If these were allowed to remain in computer memory, the students' files would eventually become so corrupted with errors that the system would cease to be useful. The students were deemed finished with the training period when they: (1) spontaneously corrected errors at a 90% level without prompting from the researcher; and (2) expressed to the researcher that a comfortable level of accuracy had been reached so that a composition could be generated without interference with normal thought processes.

All compositions were scored by two readers with previous experience reading for actual Upper Division Written Proficiency Exams. They were instructed to give a holistic score from 1 to 6, as on a normal administration of the exam, with a score of 4 and above being a passing grade. A third reader independently scored any essays that had discrepant scores. Interrater reliability between all readers was .93.

In addition to within-student comparisons across conditions, the researchers, as well as the University at large, were interested in how postsecondary students with learning disabilities fared in comparison to their non-disabled peers. Since it was known in advance that the distribution of scores on actual administrations of the Upper Division Written Proficiency Exam was not normally distributed (i.e., 75% of the scores were 4 and above) the researchers used the real distribution of a single administration of the exam taken by (presumably) non-disabled students to obtain expected frequencies of scores for the comparison. The administration counted contained over 2,300 scores and over 1,000 compositions.

In an effort to determine whether the technology may have influenced other measures of written language and to shed further light on the mechanisms by which the technology may have influenced the main variable, holistic score, compositions were analyzed on various measures used by other researchers to assess written language. Twenty-two measures of fluency, vocabulary and syntactic complexity were calculated using a variety of linguistic and computer-generated methods. A stepwise multiple regression and factor analysis were then conducted on the twenty-two measures to determine which measure, or combination thereof, influenced holistic score.

Long-term Effectiveness

In years two and three of the study the focus changed from measuring the immediate benefits of the technologies to assessing the long-term effects of their use. Information was gathered, tracked and entered into data bases concerning concrete indicators of the academic outcomes of participants, such as overall grade point averages, grades in courses with heavy reading and written language components, number of units completed per semester, probations, withdrawals, incompletes, dropouts, changes in major or area of emphasis and passage rates on the Upper Division Written Proficiency Examination.

Changes in academic behaviors were also noted. The use of computers within the Computer Access Laboratory was tracked with a logon program specifically designed to record the time on each type of software used in the Lab by each student; both participants and matched controls (described below) were tracked. The use of services was plotted from Office of Disabled Students Services data bases used to generate administrative reports each semester. Information was gathered on use of services by non-disabled students in other service centers which postsecondary students with learning disabilities also use, such as Learning Resource Center, Counselling Center, Career Center, library and other computing centers, etc. Campus and system-wide statistics were gathered from on and off campus facilities in order to make comparisons between non-disabled and learning disabled populations at the end of the study. Anecdotal records and daily diaries were compiled by the researchers describing new applications of technology which were observed in the Computer Access Laboratory (e.g. increasing speed on the speech synthesis/screen review programs to those well above normal speaking rate; use of information retrieval to "dump" references in order to save writing time; use of technology other than that upon which the students had been trained, cessation of using a piece of equipment as skills and knowledge levels indicated improvement, etc.)

Changes in the affective domain were noted anecdotally by the researchers and by the two Learning Disabilities Specialists. Notes and correspondence to researchers from participants which contained feedback on the various measures here discussed were catalogued. Informal conversations were encouraged to stay in contact with students to assess all the variables of interest to the study. Systematic phone contact was made with those participants not seen for a period of weeks or those who failed to enroll in successive semesters. Social changes were noted when observed, such as switching roles in a tutorial setting or study group from helpee to helper, changes in residence which would mark increased independence (e.g., dorm to independent living or living with a roommate), acquisition of part-time and full time employment, and use of technology on the job or to apply for a job. Increases in use of other services which would indicate acceptance of their disability was noted for those students who were newly identified. Conversely, a decrease in the use of services by previously identified students were noted (e.g., "fewer exams proctored in protected setting," "stopped using transcriber," etc.). Changes in major to a helping profession or to one which involved interaction with persons with learning disabilities or populations of related individuals such as those with emotional or other difficulties were noted. Finally, the joining of support groups, parent groups or professional organizations associated with learning disabilities were noted.

A matched group was identified of postsecondary students with learning disabilities registered with the Office of Disabled Student Services who had not participated in the study or received training on the technology during the grant period. The students were matched on semester of entry, age, sex, socioeconomic status, IQ, and as closely as possible on major and/or area of study. Each participant and his or her match were then tracked together to assess the semester-by-semester progress over the three-year period concerning all academic outcomes listed above. Use of services within the Office of Disabled Student Services was also tracked for the matched group and for participants.

As the researchers and study participants became a more visible, integrated part of the Office of Disabled Students Services, exchange of information between the service providers and research team were evident, and influenced both the direction of services offered to postsecondary students with learning disabilities through the Office as well as the direction of the efforts of the researchers. One example was the development of a system of linking specific diagnosis of cognitive abilities to the presecription of particular assistive technology. The Learning

Disabilities Specialists were already meeting with newly-identified students after assessment and suggesting various compensatory strategies which were tied to the specific academic strengths and weaknesses of each student (e.g., for a student with poor auditory memory, the suggestion might be made to carry post-it notes to take down directions for assignments, deadline dates, etc., information typically given orally in the university setting). These "suggestions" were sometimes organized into checklists of strategies which had quite naturally come to include various assistive technology available in the Computer Access Laboratory. With the sharing of information concerning the specific findings of the study (such as the finding that optical character recognition with speech synthesis assisted severely disabled readers to improve comprehension but didn't assist the more proficient readers) these prescriptions became not only more exact as to individual needs, but began to include a larger variety of assistive technologies, including those from the study.

As service providers became more familiar with the findings, more and more newly-identified postsecondary students with learning disabilities were referred for training on the technologies. Part of the mandate of the grant was to train as many students as possible on the three technologies. Although newly-identified students were being referred by the Learning Disabilities Specialists, continuing students were not necessarily aware of the study's findings and, therefore, the possible benefits they might receive by coming into the Computer Access Laboratory for training. From their experiences during year one, the researchers had already determined that one highly motivating factor in bringing in students to the study was their interest in receiving practice and feedback on passing the Upper Division Written Proficiency Exam. As noted earlier, other researchers have reported that writing difficulties constitute one of the most pressing concerns of postsecondary students with learning disabilities. In order to attract more continuing students, two "mini-courses" were designed which stressed improving written composition skills using the technologies. The mini-courses were entitled, "Passing the Upper Division Written Proficiency Exam Using Technology," and "Writing a Term Paper Using Technology" (another high-anxiety task the Learning Disabilities Specialists and researchers determined would motivate students to receive training). A "recruitment" letter was sent to all postsecondary students with learning disabilities registered with the Office of Disabled Students Services. The response was overwhelming, literally. The researchers soon found themselves unable to handle both the numbers of students requesting training and the other research demands required by the grant. Two new Instructional Support Specialists were hired part-time to work one-on-one with the students.

In selecting the Support Specialists, the researchers considered three graduate student pools of possible instructors: (1) experts in the three technologies; (2) experts in learning disabilities; and (3) experts in composition. As to the first group, all the known experts in the technologies were already working in the Computer Access Laboratory assisting students with disabilities other than learning disabilities. Experts in written composition were chosen for the following reasons. During the first year, the researchers had determined, among other findings, that measures of fluency and vocabulary were highly correlated with better scores on the essays read during the study. Because of their disability, many students had experienced failure after failure at mastering the mechanics of writing and spelling. Their writing had become more and more truncated in an effort to avoid the embarrassment of spelling and mechanical errors. Laborious efforts at remediating the problems in the past had apparently served only to further focus attention on their areas of deficit. Many students had developed a pattern of avoidance of all writing tasks, thus depriving themselves of further opportunities to catch up to their non-disabled peers. In short, students' written compositions were suffering more from their lack of experience at writing and from near phobia about it than from their actual disability. They needed to be encouraged to write more, to expand their written vocabulary to a level which approached their more mature oral vocabulary, and to bring some of the cognitive and academic strengths they possessed to their writing. For this reason, it was felt that the third group, experts in written composition, would best fit the needs of the students. English composition graduate students were accustomed to working with adult populations and were acquainted with the types of difficulties encountered by inexperienced writers caused by writing avoidance. On the other hand, graduate students in learning disabilities receive training in remediation and instruction of children with learning disabilities. First, their curriculum would have to be modified for an adult population; second, the emphasis on remediation might further focus attention on the participant's areas of deficit, rather than on developing strengths. Further, it was felt that English composition graduate students might be able to communicate the joy of writing they experienced themselves, as well as their fascination with and experimental approach to writing as a process. As it turned out, they were able to recognize talent, sometimes well-disguised amid many mechanical deficiencies, and could focus on the strengths of the students' papers. Because they were actively involved in the writing process themselves on a daily basis, they helped to dispel some of the myths inexperienced writers have about accomplished writers, i.e., that they write quickly and near flawlessly without having to plan, rewrite or edit their work. This helped students to understand which of the problems they had with their writing were due to their disability and which were "normal" difficulties faced by all writers in the process of perfecting their craft. Finally, written composition graduate students are the pool from which readers are selected for reading the Upper Division Written Proficiency Exam. They were experienced readers of actual administrations of the Exam and consequently were used to looking at the entire essay rather than focusing on one aspect such as mechanics, organization or usage.

What emerged in the mini-courses was:

1. An approach that stressed the **assistive use of technology** rather than a remedial or instructional use;
2. That encouraged **fluency, content and vocabulary expansion**;
3. That **focused on strengths** in the students' products, allowing the technology as far as possible to contend with weaknesses such as spelling, punctuation, etc.;
4. That **focused on process** and content rather than the mechanics of the written products;
5. That utilized a **one-on-one setting** to minimize embarrassment and engender trust, as well as to provide students the necessary control of the learning process to individualize pacing and instructional content to fit their particular academic and cognitive styles;
6. That utilized **creative writers** and composition personnel who could communicate the joy and benefits of the writing process; and
7. That **provided instruction** only in the form of information concerning the administration of the Upper Division Written Proficiency Exam or information regarding the mechanics of citation, etc., in the case of the Term Paper Mini-Course **only as students requested** it or as it emerged as a concern of the student while working on their projects.

Sixty more students were trained during years two and three using the "mini-course" format.

At the beginning of year three, the researchers began contacting students to readminister the questionnaire/interview given at the beginning of the study to the original eighty participants in the assessment of immediate compensatory benefits. The questionnaire covered such areas as the use of services on campus, use of technology in academic as well as other settings, study habits, use of informal methods of compensating for learning disabilities, and changes in the affective and social domains. However, on January 17, 1994, Mother Nature managed to upstage the researchers at placing California State University, Northridge "on the map" with their findings, by selecting our campus as the epicenter for the most devastating earthquake ever experienced by an American university. All 53 buildings were damaged by the quake. Between 30,000 and 50,000 people in the area around the campus were rendered homeless for weeks and months on end, including most of the students and faculty of the University. As freeway bridges disconnected and collapsed, street traffic in the Greater Los Angeles Area reached gridlock and remains there almost nine months later. The spring semester was postponed, and when it did begin, was conducted in trailer villages, makeshift tents and prefabricated domes. There was no library; there was no centralized computer network. Yet somehow, all but 16 of the original eighty students were recontacted for reinterview by the end of the semester! A few more were reached over the following summer session for a total reinterview rate of 90%.

Cost Effectiveness

Additionally in year three, a cost analysis was prepared. It should be emphasized that the evaluation of the cost effectiveness of any assistive technology is highly dependent on the context in which the analysis is conducted. Even within comparable university or college settings, many factors that can influence a realistic cost analysis will vary widely across campuses. Institutions can differ markedly on variables such as goals, purposes and policy regarding the delivery of assistive technology and other support services to postsecondary students with learning disabilities (e.g., centralized vs. dispersed delivery models). The location within the university or college system of the assistive technology delivery point can vary (e.g., office of disabled students services vs. learning resource center vs. centralized computing center, library services, etc.) budgetary policy can affect the analysis (e.g. soft vs. hard funding for technological training and/or equipment purchases). Such "givens" substantially affect the analysis results. The agency or department for whom the estimate is prepared may only be interested in the "bottom-line" or costs to their particular agency or department, or conversely may want to know the impact on larger units within the university or college system. The job assignments, education, salary rates and classification of existing personnel who might be asked to absorb new training or supervisory tasks can vary widely. The availability and willingness of volunteers, funding for student assistants and historical connection with other programs and departments who develop internship and practicum opportunities all influence the final analysis. Finally, the needs and expectations of the population of postsecondary students with learning disabilities can, of course, differ across campuses.

For the present study, the analysis was prepared in terms of the costs which would be incurred by the service delivery point for assistive technology at California State University, Northridge, the Office of Disabled Students Services which was a well-established office with a highly-trained technical support staff, a history of attracting many student volunteers and adequate funding for several student assistants to provide a variety of services for students with disabilities, including learning disabilities. Elements included in the analysis were the initial cost of equipment and training, and supervisory/monitoring costs once students were trained, given current staffing and salary schedules. The estimate was then adjusted for projected increases in use of assistive technology services and other support services using data gathered from the questionnaire given to students from the study, and on logon times taken from the Computer Access Laboratory.

The estimate was then compared to the cost of providing equivalent non-technological services such as transcribers, readers, tutors, counsellors and notetakers, given current staffing and salary schedules. Two estimates were computed: (1) a minimal "bottom-line" cost estimate which covered initial equipment purchases, initial training costs and post-training monitoring needs for the projected number of students likely to request services; and (2) a maximal estimate which, in addition to the costs listed under (1), included some student outreach to previously identified learning disabled students, needs assessment activities of the current population of students with learning disabilities and the provision of specialized training based on the needs assessment.[4]

E. Evaluation/Project Results

1. Immediate Compensatory Effectiveness

a. Optical Character Recognition/Speech Synthesis and Reading Comprehension

There was no significant difference between the means across conditions. This was due to the fact that the technology raised scores for severly disabled readers but interfered with performance for proficient readers. In fact, when scores on the "No Assistance" condition were arranged from lowest to highest, and scores on the technology-assisted readings were plotted against them, an inverse correlation emerged (see Figure 1). A Pearson's correlation coefficient proved to be highly significant ($p > .001$). The relationship is even clearer in Figure 2, where only differences between the scores are plotted. (Silent reading scores are plotted along the "zero" axis and technology-assisted scores appear either above or below the line.) Stated simply, the greater the disability in reading comprehension, the more likely it was that the technology would assist students in compensating for their difficulties. Figure 3 represents plottings for the "Read Aloud" condition. A similar, but weaker correlation was evident ($p > .01$). The finding that both speech synthesis and human readers improved the scores for disabled, but not for more proficient readers, indicates that auditory presentation of text, regardless of the mode of presentation, has varying effects on comprehension, dependent upon the skill level of the reader.[5]

Various explanations could be offered to account for the above results. The most plausible to the researchers and that which most closely agrees with the research of others, is that the technology was assisting students who were struggling to sound out each word of text by circumventing the decoding process altogether, thus freeing the "central cognitive processor" for the comprehension task. As to the interference with the proficient readers' scores, it was suggested by the researchers that as the better readers reached the more complicated passages in the later paragraphs on the reading test, the phrases within a sentence were coded in phonological short term memory, in order to untangle convoluted syntax. The auditory presentation of text

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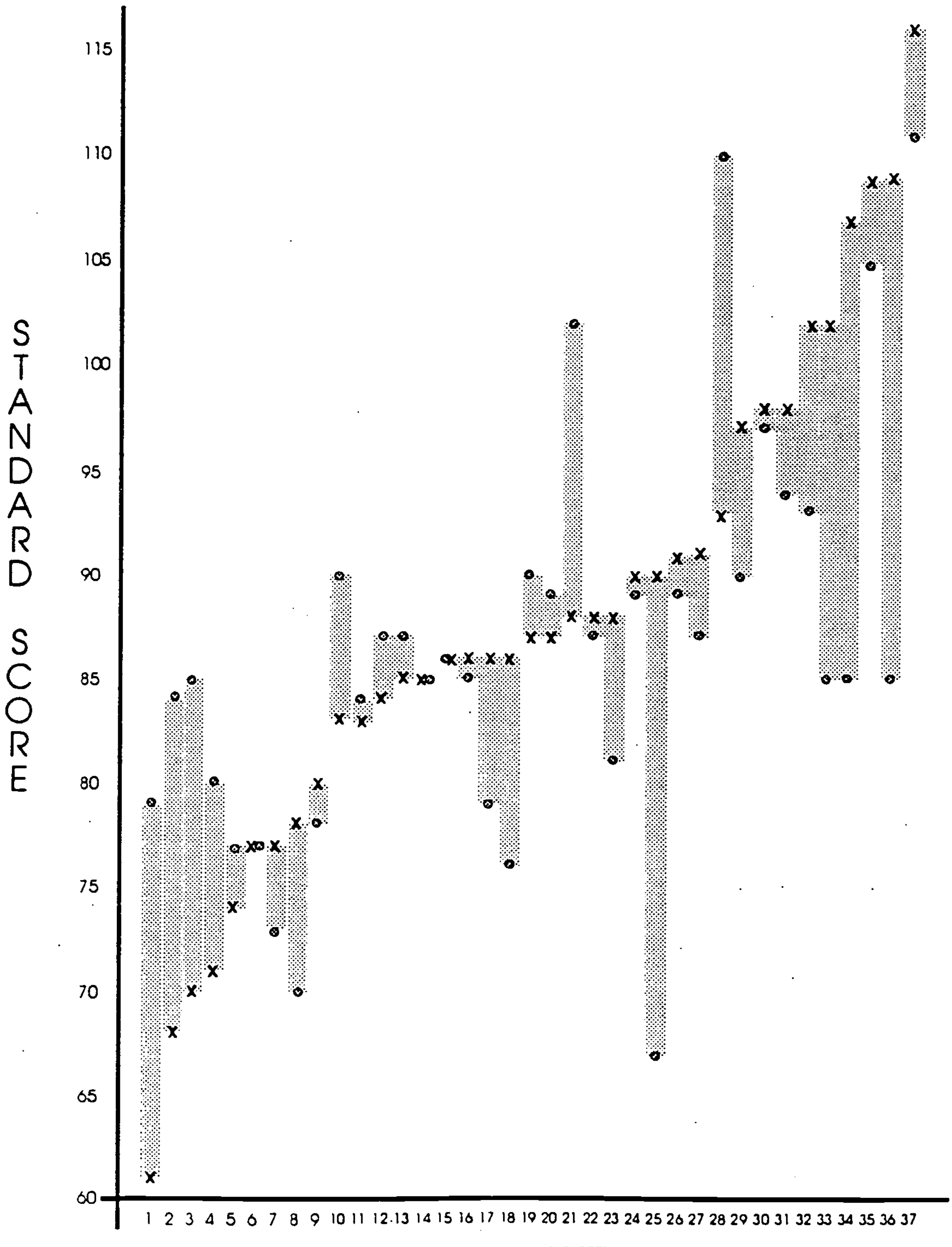
[4] The maximal amount was based on actual outreach, needs assessment and service provision costs which were incurred during years two and three of the study. The needs assessment conducted in year two determined that two areas of need were salient to participants in the study—passage of the Upper Division Written Proficiency Exam and instruction/guidance on how to write a term paper. Two "mini-courses" were developed entitled, "Writing a Term Paper Using Technology," and "Passing the Upper Division Written Proficiency Exam Using Technology." Flyers were sent out to all students with learning disabilities each semester. Sixty students responded and subsequently participated in the mini-courses.

[5] The findings agree with Harker & Feldt's research conducted on secondary students with and without reading disabilities who took the Iowa Test under a silent reading condition and an audiotape augmented condition. Students with reading disabilities did better under the audiotape condition while non-disabled students did not. This evidence was used by those investigators to refute the claim that persons with learning disabilities might be receiving an unfair advantage when allowed to use compensatory strategies during the administration of standardized tests (i.e. the augmented condition did not improve scores unless the subject had a legitimate reading deficit).

interfered with this process, thus disrupting comprehension. The less proficient readers did not experience the interference because they never got far enough into the test to reach these complicated passages (Higgins & Raskind (in submission)).

STANDARD SCORE
No Assistance vs. Speech Synthesis



X = Score under 'no assistance' condition
o = Score under 'speech synthesis' condition

Fig. 1

DIFFERENCE SCORES
No Assistance vs. Speech Synthesis

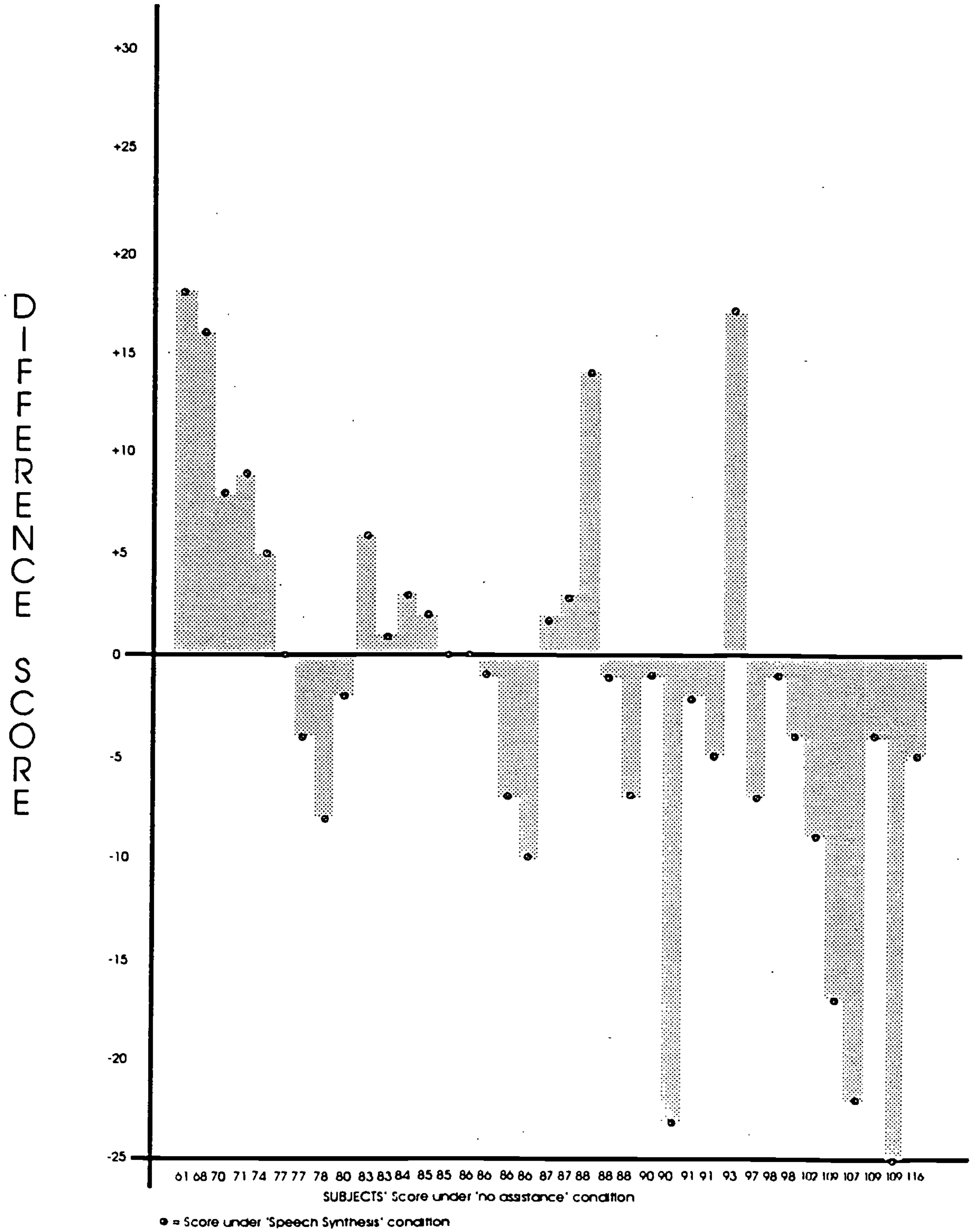


Fig. 2

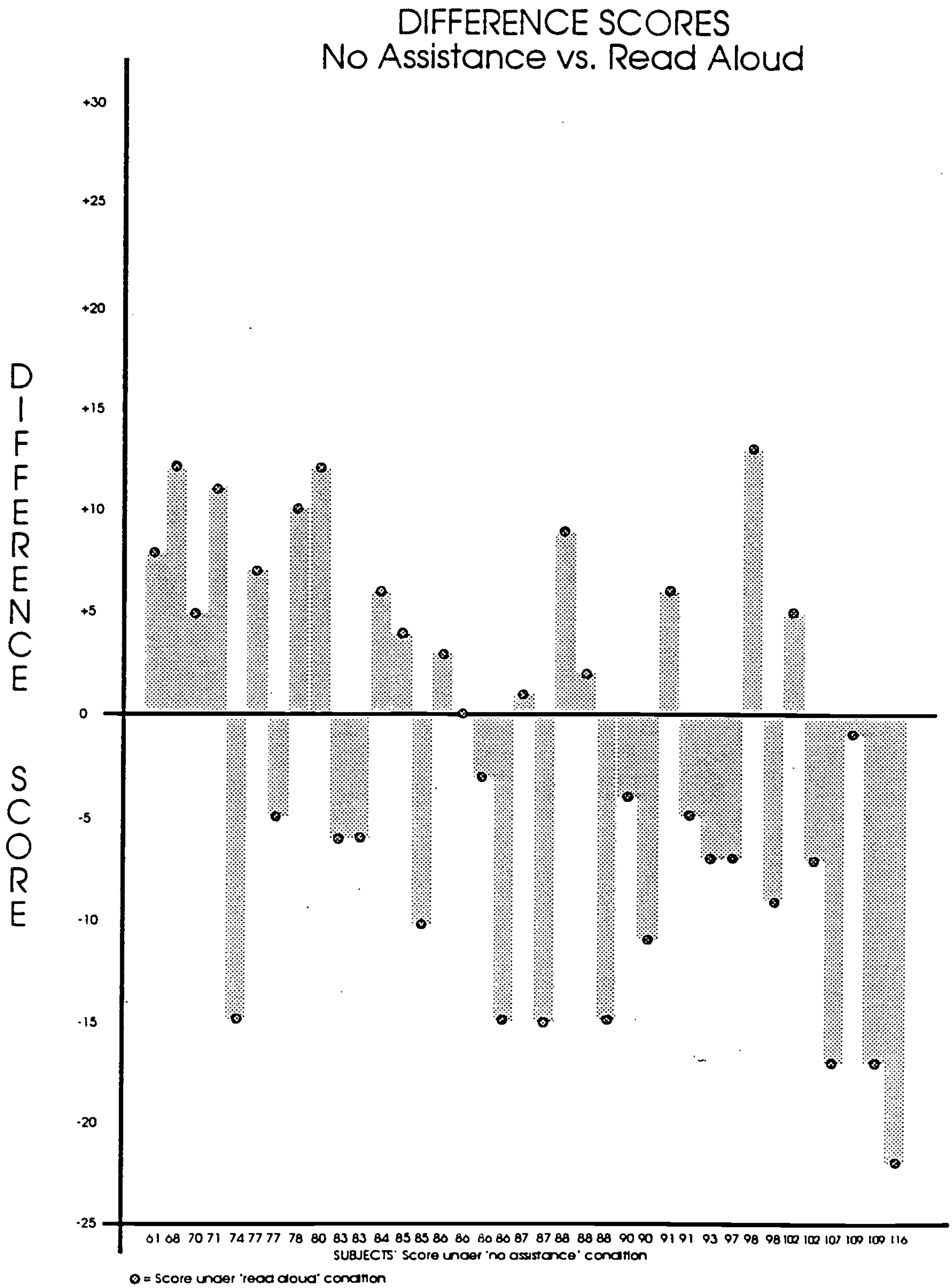


Fig. 3

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b. Speech Synthesis/Screen Review and Proofreading

Postsecondary students with learning disabilities found significantly more errors overall using speech synthesis/screen review than when read aloud to ($p > .04$) or when receiving no assistance ($p > .00005$). The "read aloud" condition also improved the number of errors found significantly ($p > .0001$) over receiving no assistance. As to categories of errors, students using the speech synthesis/screen review found more errors in seven of the nine categories, four at a significantly higher level: capitalization, spelling, usage and typographical categories when compared to receiving no assistance. The read aloud condition fared better than no assistance on three categories: spelling, usage and grammar/mechanical errors. When speech synthesis/screen review is compared to the read aloud condition, speech synthesis/screen review did better for two categories: capitalization and usage. Results are summarized below in Figure 4.

Percentages of Errors Found by Condition and Category

Category	Condition		
	SS	RA	NA
Capitalization	33**	18	19
Punctuation	18	16	15
Spelling	48*	45*	33
Usage	33**	6	17*
Grammar-Mechanical	22	35**	20
Grammar-Global	29	26	24
Typographical	61*	52	40
Content/Organization	11	10	13
Style	33	21	18

* Significant when compared to one other condition

** Significant when compared to both other conditions

The fact that both the speech synthesis/screen review and read aloud conditions did better than no assistance is consistent with the findings of other researchers, that listening to text enhances the ability to identify errors (Alley & Deshler, 1979; Johnson & Myklebust, 1967; Espin & Sindelar, 1988). A plausible explanation is that listening and seeing the error at the same time creates a mental "mismatch" (between visual and auditory signals) which alerts the reader to the error. Speech synthesis/screen review may have done better than the human reader for the reason that human readers have a tendency to read what they expect to be there, given the context, rather than what is actually written, whereas the speech synthesis/screen review system will robotically repeat what is on the page. Another possible explanation is that speech synthesis/screen review creates a closer visual/auditory matching of words than is possible with a human reader. The proofreader may or may not have his or her eyes on the word being pronounced by the human reader, whereas the highlighting of the text while synthesizing it compels the proofreader to move his or her eyes along to the appropriate word. Or, it may be that the computer and speech synthesis/screen review medium is simply more interesting and involving than print to persons with learning disabilities, which encourages rereadings at a higher rate (Raskind & Higgins (in press)).

c. Speech Recognition

Holistic scores on essays using speech recognition (SR) were superior to those written with no assistance (NA) for a significant number of the 26 participants in the study (SR=13 and NA = 5, p=.048). Those dictated to a transcriber (TR) were also better for many participants, but their numbers did not reach significant level (TR=11 and NA=6, p=.067). Speech recognition essays were scored higher than transcribed essays for eight students, while six students did better for the transcribed essay than on the speech synthesis essay, which did not reach significance (SR=8, TR=6, p=.90).

When comparing the distribution of scores of the postsecondary students with learning disabilities to their non-disabled peers under the no assistance condition, the learning disabled population scores were significantly lower (p>.0001). Under the transcribed condition, the learning disabled essays were also significantly lower (p=.002). However, when using speech recognition the distribution of scores more closely resembled those of the non-disabled population and in fact **did not differ significantly** from them (p>.112). The speech recognition apparently succeeded in "leveling the playing field" for postsecondary students with learning disabilities. Of the twenty-two measures of fluency, vocabulary and syntactic complexity, only one signficantly differed across conditions--the ratio of words with seven or more letters to total words in the essay, in favor of speech recognition. Many of the measures of fluency, vocabulary and syntactic complexity showed high correlations with holistic scores. A multiple regression run on all the measures revealed that the best single predictor of holistic score was words with seven or more letters. A factor analysis was done on all the measures and showed that there were six factors which emerged as "clusters" of measures that varied together, three of which proved to be strong predictors of holistic score: Factor 1, measures related to length of the essay, Factor 2, measures related to vocabulary, and Factor 3, number of main verbs. Roughly interpreted, the experienced readers of the essays, who were, of course, blind as to the condition under which the essay was written, responded to (1) length of the essay (2) sophistication of the vocabulary and (3) number of action verbs in the writings.

Since the only variable which differed across conditions was the ratio of long words (words of seven or more letters) to words in the essay, and long words turned out to be the best predictor of holistic score, the researchers surmised that the technology may have encouraged the use of longer words over the other two conditions. The mechanism by which this phenomenon could have occurred is as follows. A frequently reported compensatory strategy used by persons with learning disabilities is to substitute a "baby" word (short word) for a longer one the student actually wants to use, in order to avoid the embarrassment of a misspelling. However, the speech recognition system is better at guessing correctly for longer, multisyllabic words than with short monosyllabic ones. This is because there is more phonetic information to go on with the multisyllabic words, hence less chance of confusing the word with a similar word from the 30,000 word English vocabulary. Students noticed this tendency for the equipment to make better guesses with the longer words, often commenting on it, and in an effort to get the system to stop stumbling quite so much, would choose the longer word over a short one, thus counteracting their tendency to use limited, truncated vocabulary (Higgins & Raskind (in press)).

2. Academic Outcomes

Participants in the first year's formal study as well as those who received training on the technologies during years two and three showed several positive academic outcomes. (Results are summarized in Figure 5 below.) Passage rates on the Upper Division Written Proficiency Exam showed significant improvement for the trained group. Of the 140 participants, 42 took the exam and 40 passed on their first attempt (95%). The overall passage rate for the non-disabled CSUN population is 75%; passage rates for students with learning disabilities registered with the Office of Disabled Students Services in years previous to the beginning of the study were approximately 50% as was the rate for the matched group of learning disabled subjects who had not received training (52%). Their grade point averages for courses with heavy reading and/or composition requirements were significantly higher ($p > .05$), although these gains were not sufficient to increase overall grade point averages so that they reached significance.

ACADEMIC OUTCOMES

	PARTICIPANTS YEAR ONE (80)		PARTICIPANTS YEAR TWO-THREE (60)		ALL PARTICIPANTS (140)		MATCHED CONTROLS (140)		CSUN NON-DISABLED	
	Prestudy	F'91-S'94	Prestudy	F'91-S'94	Prestudy	F'91-S'94	Prestudy	F'91-S'94	Prestudy	F'91-S'94
Overall GPA	2.52	2.61	2.62	2.81	2.56	2.70	2.54	2.41	--	--
Academic Courses	2.03	2.56	2.43	2.72	2.20	2.63	1.96	2.02	--	--
Graduations Rates per semester	--	11.3%	--	23.3%	--	16.4%	--	5%	--	--
Withdrawals, Incompletes	.69	.48	.40	.12	.57	.33	.73	.47	--	--
Makeup Rate	.42	.74	.46	.96	.44	.83	.48	.43	--	--
Dropout, Flunkout	--	2.5%	--	0%	--	1.4%	--	33.6%	48%	--
Upper Div. Written Prof. Exam.	49.6%	95.2%	52.3%	95.2%	50.1%	95.2%	44%	52%	73%	75%

The most striking findings were in the area of retention rates. Only two students left school or were disqualified out of the 140 participants over the three-year period (1.4%). This result was impressive considering that the attrition rate for non-disabled students at the University is 48% over four years (CSU Stateline, 1994) and was 33.6% over the same three-year period for a matched group. Further, although the participants in the study received similar numbers of withdrawals and incompletes as the matched group, they showed higher rates of repeating the courses until a satisfactory grade was obtained. This finding, along with the information below on differences between the use of services of the participants and the matched controls, would indicate that when participants ran into trouble with unsatisfactory grades or an inability to keep up, they sought help through the Office of Disabled Students Services, repeated the courses in which their performance had been deficient, and persisted toward their degree. The matched group, on the other hand, when faced with similar difficulties, quietly dropped out or flunked out of school, without ever seeking assistance.

It is difficult to say whether the participants in the study differed along some personal variable from the matched controls, such as "persistence," "acceptance of disability," or "propensity for use of technology." which would explain both their willingness to seek help and their participation in the study. Other researchers (Gerber, Ginsberg & Reiff, 1992; Spekman. Goldberg & Herman, 1992; Vogel & Adelman, 1990) have noted that such traits (along with positive self regard, self-advocacy, and participation in groups which advocate the rights of persons with learning disabilities) tend to co-vary across adults with learning disabilities, and to be associated with success. However, two pieces of evidence would favor attributing differences in the matched and study groups to the training on the technology and/or participation in the study (perhaps by acting as a catalyst for the development of the cluster of "successful" traits). First, makeup rates (an indication of "persistence") were similar for both the study participants and matched groups previous to the study (.44 and .48 respectively); but after participation in the training, the study group increased their rate of makeups while the matched group did not (.83 and .43 respectively). Secondly, content analysis of responses from the post-training questionnaire adminsitered to the study group frequently named the computer specifically as being responsible for their success. For example, nearly half the respondents uttered the direct quote, "the computer has changed my life [for the better]." (More is reported on affective changes in the sections which follows.)

3. Academic Behaviors, Attitudes, and Affective and Social Domains

Pre and posttest questionnaire responses of the participants in year one's formal study (supplemented by logon records from the Computer Access Laboratory) revealed several changes in academic behaviors and in the use of compensatory strategies including the use of assistive technology. There was a 78% increase in hours of use of assistive technology in general, which was accounted for primarily by greater use of word processing. The increased use of word processing, according to participants' responses, was partially due to improvement in keyboard skill and typing speed stimulated by their participation in the study, which in turn allowed them to become more efficient writers. However, there was an additional positive effect of having received training. More than 75% of the respondents reported that they had begun putting their word processors to use for academic purposes other than composition, such as note-taking, organizing course content, outlining reading material, and time and deadline management. Further, 90% reported extending the use of computers into at least one non-academic setting, including actual employment assignments, job searching, and for recreational and social purposes. Additionally, purchases of home computer equipment was reported by over half the participants. In addition to word processing, the use of variable speed tape recorders and books on tape also increased. In terms of the three technologies under study, logon times for computers located in the Computer Access Laboratory indicated an eight-fold increase in the use of the three technologies by persons with learning disabilities, all but 3% of which was accounted for by persons who had participated in the study in either year one, or in the writing mini-courses conducted during years two and three.

The data bases kept by the Office of Disabled Students Services indicated changes in the use of compensatory strategies other than assistive technology. Students who had been recently identified through the Office of Disabled Students Services tended to increase the use of services offered by both the Office and other campus service providers as a result of their first-time exposure to these services during participation in the study (35% increase). Students who had been identified previous to entering CSUN tended to decrease their use of services over years two and three, indicating increased independence from institutionalized forms of support (22% decrease). This was corroborated by the questionnaire responses of participants in their post interview session. For both newly-identified and previously-identified students, however, there was an overall drop in use of informal sources of outside assistance such as family members, classmates and fellow employees to assist them with reading and written language tasks (45%). The matched group tended to use few services through Office of Disabled Students Services in comparison to those students who participated either in the formal study in year one or the writing courses in years two or three, according to the data bases kept by the Office (participants averaged 2.4 requests for various types of service; the matched group .86). Considering the matched groups' higher dropout rate, it would not be plausible to assume they use fewer services because they didn't need them. It would seem more likely that there were motivational or personal variables which might better explain their less frequent use of services, such as the cluster of "success" traits alluded to above.

Changes in attitudinal and affective variables were assessed using the Dimensions of Self Concept (Michael, Smith & Michael, 1989). Significant differences were found on three of the five scales: Identification vs. Alienation, Leadership and Initiative, and Academic Interest and Satisfaction. Content analysis of free responses to questionnaire items confirmed these findings and further indicated that participation in the study was responsible (at least in the minds of participants) for the improvement in their self-concept. Forty-six percent of the respondents uttered the reply, "the computer has changed my life [for the better]." Sixty-six percent of the respondents reported having learned more about their strengths and weaknesses and about learning disabilities in general as a result of their participation and/or training. Eighty percent expressly stated feeling, "better about myself," when asked whether the study had been useful to them since their participation.

4. <u>Cost Effectiveness</u>

It was determined that the net savings for the Office of Disabled Students Services for the minimal services was $320 per student, per semester, and $260 for the maximal services. The amount was then adjusted for projected increases in the use of other computer services within Office of Disabled Students Services and from other campus service providers, for a net benefit of approximately $310 for the minimal service provision and $234 for the maximal service provision per student, per semester.

5. <u>Dissemination</u>

The study yielded six publications in major refereed journals in learning disabilities (*Learning Disability Quarterly*, *Journal of Learning Disabilities*, *Annals of Dyslexia*). In addition, four papers have appeared in proceedings of the annual Technology for Persons with Learning Disabilities conference sponsored by California State University, Northridge CENTER ON DISABILITIES on various phases of the study. Presentations at various national and international professional conferences included fourteen international and national conferences. Workshops offered by California State University, Northridge Office of Disabled Student Services and

CENTER ON DISABILITIES were also opportunities for dissemination to interntional and national audiences. These included presentation to the U.S. Department of Rehabilitation, District 9, the Advisory Board of Rehabilitation Services, and a conference for employers which drew participants from national and international organizations (See Appendix A for a complete list of publications and presentations). On campus activities included annual and bi-annual presentations by Office of Disabled Students Services staff to various faculty and support services units, including the Career Center, Counselling Center, Learning Resources Center, Library and Central Computing Center, Upper Division Written Proficiency Exam Office, English Department composition faculty, Department of Educational Psychology, and Department of Special Education. Finally, the Office of Disabled Students Services and CENTER ON DISABILITIES staff continued and broadened its previous on and off-campus efforts to promote the use of technology by persons with learning and other disabilities at California State University, Northridge through participation on various committees and organizations and to use its extensive historical connections with service providers and manufacturers at the state, national and international level to seek community and private sector support for the development of assistive technology for persons with disabilities, including learning disabilities.

F. Summary and Conclusions

First, to summarize the findings for all three studies on the immediate compensatory effectiveness of the three technologies, the reading, proofreading and written composition difficulties experienced by postsecondary students with learning disabilities were best ameliorated using the technology, with the human readers and transcribers coming in a fairly close second. It should be pointed out, however, that the technology did not work equally well for all students,[6] nor for all tasks; there was great variation in its effectiveness across subjects for all three studies, depending on students' academic and cognitive profiles. The results on immediate compensatory effectiveness, taken as a whole, suggest that a careful assessment of strengths and weaknesses for each individual should be tied to a prescription of specific, appropriate technology.

Secondly, postsecondary students with learning disabilities require computer training techniques that differ from those used for other types of disabilities and for non-disabled populations. The experience of the researchers suggest that the following guidelines were found helpful in training this diversified population: (1) utilize a one-on-one setting for computer training. It allows students to maximize control over the pacing and content of the learning process so that each student can best accommodate and compensate for his or her learning disability; (2) plan to include more repetition and review of instructions and allocate more time for this purpose than when working with other disabilities or with non-disabled populations. Persons with learning disabilities frequently experience interference from their disability, often necessitating a second run-through of an the instructional routine; (3) limit instruction on the use of the computer to compensatory rather than remedial or instructional purposes. As noted previously, focus on the disability can increase embarrassment and shame and result in avoidance of the technology; (4) be alert to possible adaptations that may be necessary when training on equipment never before used by students with learning disabilities. The use of specific equipment by learning disabled students will frequently differ from its use by other types of disabilities, and sometimes from that of non-disabled populations; (5) utilize formal and informal objective means of assessing performance and hence the efficacy of the use of a particular technology, to reinforce

[6] In the case of reading comprehension, it actually appeared to interfere with performance of highly skilled readers.

"impressions," stated by the user or the instructor (technology can be "dazzling," without having real impact on performance); (6) on the other hand. students can experience unanticipated long-term benefits from the use of assistive technology. Encourage the students to work with a piece of equipment at least until a level of comfort and "automaticity" is reached.

Third, the study found that postsecondary students with learning disabilities have a specific need to enhance fluency and expand the vocabulary of their writing. The authors found the development of a writing program based on the compensatory use of assistive technology extremely helpful to the population as a whole in assisting students to improve the quality of their written compositions. Considerations for developing such a program are enumerated in the results section of this report.

Fourth, although assistive technology cannot be considered a replacement for people, it tended to outperform human helpers such as transcribers, readers and proofreaders, was found to be more cost effective than employing such personnel and was found to have lasting social/emotional benefits, such as increased independence and enhanced self-esteem.

Fifth, long-term improvement in academic outcomes and behaviors as well as positive changes in social and affective variables can be expected with the use of assistive technology. The use of a particular piece of assistive technology may allow access to information previously unavailable to the student which in turn can open up new content domains or permit understanding of material from presentation formats previously denied the student due to his or her disability. For example, speech synthesis/screen review may allow a student to finish a reading assignment in time for class, and thus for the first time, be fully prepared for a lecture. It was clear from content analysis of participants' responses on the questionnaire/interview and from the objective, measurable results of the academic outcomes of the study that compensatory effectiveness was not limited to immediate relief of the participants' learning difficulties, but would be better characterized, in the words of several informants, as "starting me on a positive roll."

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Additional Apendices

Appendix A: Publications and Professional Presentations

Appendix B: Publications Related to Findings (five)

Appendix C: Questionnaire/Interview Schedule on Use of Assistive Technology, Use of Campus Services and Formal and Informal Compensatory Strategies

Appendix D: Course Outlines for Mini-courses in Utilizing Assistive Technology to Enhance Written Composition Skills; "Recruitment" letter and flyers

Appendix E: Sample Lesson plans for training on a Speech Recognition System as an Assistive Technology for Postsecondary Students with Learning Disabilities

APPENDIX A

Publications and Professional Presentations

Appendix A: Publications and Professional Presentations

Publications in Professional Journals:

Higgins, E.L. & Raskind, M.H. (in press). An investigation of the effectiveness of speech recognition on the written composition of postsecondary students with learning disabilities. *Learning Disability Quarterly*.

Raskind, M.H. & Higgins, E.L. (in press). The effects of speech synthesis on the proofreading efficiency of postsecondary students with learning disabilities. *Learning Disability Quarterly*.

Raskind, M.H. & Higgins, E.L. (in press). Reflections on ethics, technology and persons with learning disabilities: Avoiding the consequences of ill-considered actions. *Journal of Learning Disabilities*.

Raskind, M.H. & Higgins, E.L. (in press). Recent research on technology for postsecondary students with learning disabilities. *Journal of Learning Disabilities*.

Higgins, E.L. & Raskind, M.H. (submitted). The compensatory effectiveness of optical character recognition/speech synthesis on the reading comprehension of postsecondary students with learning disabilities. *Journal of Learning Disabilities*.

Higgins, E.L. & Zvi, J. (submitted). The compensatory effectiveness of assistive technology with postsecondary students with learning disabilities: From research to practice. *Annals of Dyslexia*.

Papers presented at the California State University, Northridge sponsored Annual International Conference on Technology and Persons with Disabilities and published in the Proceedings:

Higgins, E.L. & Curtis, A. (1994). "State-of-the-art technology and adults with learning disabilities."

Higgins, E.L. (1994). "Assistive technology and postsecondary students with learning disabilities: From Research to Practice."

Higgins, E.L. & Curtis, A. (1993). "How to maximize the use of technology for persons with learning disabilities."

Higgins, E.L. & Raskind, M.H. (1993). "An investigation of the compensatory effectiveness of assistive technology on postsecondary students with learning disabilities: Preliminary findings."

Presentations at national and interntional conferences and symposiums:

Higgins, E.L. "State-of-the-art Technology and Postsecondary Students with Learning Disabilities: From Research to Practice." **Annual National Conference of AHEAD** (Association of Higher Education Administrators for Disabilities), Columbus, Ohio, July, 1994.

Higgins, E.L. & Zvi, J. "Assistive Technology for Postsecondary Students with Learning Disabilities: From Research to Practice." **California State Conference of Learning Disabilities Association,** Pomona, California, October, 1993.

Higgins, E.H. & Raskind, M.H. "Compensatory Effectiveness of Assistive Technology with Postsecondary Students with Learning Disabilities: Results of the First Year." **International Conference of the Council on Learning Disabilities**, Baltimore, Maryland, October, 1993.

Higgins, E.L. & Raskind, M.H. "An Investigation of the Compensatory Effectiveness of Speech Recognition on the Written Composition Performance of Postsecondary Students with Learning Disabilities." **Third International Symposium for Persons with Learning Disabilities sponsored by The Frostig Center, Misillac,** France, July, 1993.

Raskind, M.H. & Higgins, E.L. "The Effects of Speech Synthesis on the ProofreadingEfficiency of Postsecondary Students with Learning Disabilities." **Third International Symposium for Persons with Learning Disabilities sponsored by The Frostig Center, Misillac, France,** July, 1993.

Higgins, E.L. & Raskind, M.H. "An Investigation of the Compensatory Effectiveness of Assistive Technology on Postsecondary Students with Learning Disabilities: Preliminary Findings," **Learning Disabilities Association of America International Conference,** San Francisco, California, February, 1993.

Higgins, E.L. & Curtis, A. "Assistive Technology for Persons with Learning Disabilities." Annual Training Conference, **National Rehabilitation Association,** San Diego, California, December, 1992.

Raskind, M.H. & Higgins, E.L. "An Investigation of the Compensatory Effectiveness of Assistive Technology on Postsecondary Students with Learning Disabilities: Preliminary Findings." **Fourteenth International Conference of the Council for Learning Disabilities,** Kansas City, Missouri, October, 1992.

Raskind, M.H. & Higgins, E.L. "Technologies for Persons with Learning Disabilities: An Overview." **California State Conference of Learning Disabilities Association,** La Jolla, California, October, 1992.

Raskind, M.H. & Higgins, E.L. "An Investigation of the Compensatory Effectiveness of Assistive Technology on Postsecondary Students with Learning Disabilities: Preliminary Findings." **California State Conference of Learning Disabilities Association,** La Jolla, California, Octiber, 1992.

Higgins, E.H. & Pickering, G. "Technology for Persons with Learning Disabilities." conference of **Arizona State Learning Disabilities Association,** Tucson, Arizona, September, 1992.

Higgins, E.H. & Axelrod, L. "Technology for Persons with Learning Disabilities." **AHSSPPE Annual Conference,** Los Angeles, California, July, 1992.

Higgins, E.H. & Zvi, J. "Technology for Persons with Learning Disabilities." Regional Conference of **Arizona Rehabilitation Services Administration,** June, 1992.

Workshops offered by California State University, Northridge Office of Disabled Students Services and CENTER ON DISABILITIES:

"Assistive Technology and Persons with Learning Disabilities." Leadership Conference of U.S. Department of Rehabilitation, District 9, June, 1994.

"Compensatory Effectiveness of Assistive Technology on Postsecondary Students with Learning Disabilities: The First Year's Results." Advisory Board of Rehabilitation Services, June, 1993.

"Learning Disabilities in the Workplace." Conference for Employers, February, 1993.

Media Presentations:

"Technology and Persons with Learning Disabilities," Interview on KIEV AM, Los Angeles Weekly Radio Program, "Technology and Persons with Disabilities," June 27, 1994.

APPENDIX B

Publications Related to Findings

1. Higgins, E.L. & Raskind, M.H. (in submission). The compensatory effectiveness of optical character recognition/speech synthesis on the reading comprehension of postsecondary students with learning disabilities. *Journal of Learning Disabilities*.

2. Raskind, M.H. & Higgins, E.L. (in press). The effects of speech synthesis on the proofreading efficiency of postsecondary students with learning disabilities. *Learning Disability Quarterly*.

3. Higgins, E.L. & Raskind, M.H. (in press). An investigation of the effectiveness of speech recognition on written composition of postsecondary students with learning disabilities. *Learning Disability Quarterly*.

4. Higgins, E.L. & Zvi, J.C. (in submission). The compensatory effectiveness of assistive technology with postsecondary students with learning disabilities: From research to practice. *Annals of Dyslexia*.

5. Raskind, M.H. & Higgins, E.L. (in press). Assistive technology for postsecondary students with learning disabilities. *Journal of Learning Disabilities*.

The Compensatory Effectiveness of

Optical Character Recognition/Speech Synthesis

on Reading Comprehension

of Postsecondary Students with

Learning Disabilities[1]

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Running Head: OCR/SPEECH SYNTHESIS & READING COMPREHENSION

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ABSTRACT

The study investigated the compensatory effectiveness of optical character recognition in conjunction with speech synthesis on the reading comprehension of postsecondary students with learning disabilities. Subjects were given a reading comprehension test under the following three conditions: (1) using an optical character recognition/speech synthesis system; (2) having the text read aloud by a human reader; and (3) reading silently, without assistance. There was a significant inverse correlation between the silent reading comprehension score and the score obtained using optical character recognition/speech synthesis such that the greater the disability, the more the technology elevated comprehension; conversely, the higher the silent reading score, the more an apparent interference effect depressed performance ($p=.001$). A similar, but weaker correlation was also found between the silent reading comprehension score and the read aloud condition ($p=.01$). Results are discussed in light of research on the cognitive processes involved in the decoding and comprehension of written material.

Since 1985, the number of students with learning disabilities entering postsecondary institutions has grown faster than any other disability classification (American Council on Education, HEATH Resource Center, 1992). This increase is likely to continue for some time considering the fact that there are over 100,000 students with learning disabilities exiting high school every year (Office of Special Education Programs, 1992) and that as many as 67% have plans for some type of postsecondary education (White et al., 1982). Although statistics are not readily available as to the precise number of postsecondary students with learning disabilities, data from the American Council on Education (1992) and the National Center for Education Statistics (1989) suggests that the figures range from approximately 160,000 to 300,000. In fact, according to Jarrow (1987) students with learning disabilities are the "single largest contingent of students with disabilities being served on American campuses." (p. 46)

This burgeoning population of students with learning disabilities, coupled with federal legislation (Section 504 of the Rehabilitation Act of 1973) mandating "academic adjustments" for persons with disabilities, has prompted the development of learning disability support service programs aimed at promoting academic retention and success (Beirne-Smith & Deck, 1989; Vogel, 1987; Vogel & Adelman, 1993). One area in which support service programs often provide assistance to students with learning disabilities is reading. This is not surprising considering that reading problems are one of the most frequently reported difficulties of adults with learning disabilities (Blalock, 1981; Cordoni, 1979; Prater & Minner, 1986). In efforts to help students with reading difficulties, postsecondary support programs provide such services as access to books on audiotape, offering tutors for help with specific content areas, and providing human readers for students during exams and to assist with class assignments (Bryant, Rivera & Warde, 1993; Mangrum & Strichart, 1988; Mellard, 1994; Shaw, McGuire & Brinkerhoff, 1994; Vogel & Adelman, 1993).

In addition to the above mentioned services, an increasing number of postsecondary support programs are showing interest in the use of optical character recognition (OCR) systems combined with synthetic speech technology to compensate for reading disabilities (Brown, 1987; Bryant, Rivera & Warde, 1993; Raskind & Scott, 1993). These computer-based "reading machines" scan and convert hard copy text (e.g., a page in a book) to electronic text, which is then read aloud by means of a speech synthesizer. It has been suggested that such systems may help some postsecondary students with learning disabilities (specifically, those who have oral language abilities superior to their written language abilities (Aaron & Phillips, 1986)) compensate for reading difficulties since it enables the user to hear, as well as see text (e.g., Brown, 1987; Raskind & Scott, 1993).

According to *The K & W Guide: Colleges and the Learning Disabled Student* (Kravitz & Wax, 1993), 37% of the 199 colleges/universities listed in the publication indicate that they have OCR/speech synthesis systems available to students with learning disabilities, and indications are that this percentage is likely to increase. For example, Kurzweil Computer Products, the largest manufacturers of OCR/speech synthesis systems, reports that sales of their OCR systems (which are specifically designed for persons with learning disabilities) to postsecondary institutions have increased substantially over the last two years and are expected to continue to increase on a steady basis (G. Guidice, Director of Marketing, personal communication, September, 1994). Although it may be difficult to determine the precise reasons for the increased use of these systems among postsecondary learning disability support service programs, there are several possibilities. First, although no controlled research is available on the effects of OCR/speech synthesis on the comprehension of postsecondary students with reading difficulties, learning disability support service providers may be operating under the assumption that OCR/speech synthesis systems will circumvent reading deficits, since it converts text to speech, thereby "playing" to the presumed superior oral language abilities (as compared to written language abilities) of students with learning disabilities. It is also possible that the growing use of technology is the result of the increasing financial and personnel demands of providing services to the rising number of postsecondary students with learning disabilities (Vogel, 1987), as well as efforts to provide a reading strategy that can foster independence (Bryant, Rivera & Warde, 1993; Raskind, 1994). Furthermore, recent improvements in accuracy and speed of scanning, speech quality, and screen review software programs (specifically for learning disabilities) may have fostered increased interest. Finally, reductions in the cost of the technology may have made their purchase more feasible for many learning disability support service programs.

Unfortunately, while the use of OCR/speech synthesis systems among postsecondary learning disability support service programs continues to grow, as previously mentioned, there is little controlled research to support its efficacy as a compensatory reading strategy. Indications of the presumed benefits of OCR/speech synthesis have been predominantly derived from case studies and anecdotal reports (e.g., Brown, 1987; Bryant, Rivera &

Warde, 1993; Raskind & Scott, 1993). Although research in OCR/speech synthesis and learning disabilities has been conducted (e.g., Elkind, 1993; Leong, in press; Torgesen & Barker, in press) the focus of these studies has been on the remediation of reading disabilities in children, rather than on the compensatory effectiveness of the technology for adults with learning disabilities.

In response to the lack of research in this area, the present study (part of a three-year study on the effects of assistive technology on postsecondary students with learning disabilities funded by the U.S. Department of Education, Fund for the Improvement of Postsecondary Education) investigated the effectiveness of OCR/speech synthesis as a compensatory strategy for postsecondary students with reading disabilities.[2] Specifically, the purpose of this study was to determine whether an OCR/speech synthesis system which presented text on a computer screen, and visually highlighted words as they were simultaneously "spoken," would enhance the reading comprehension of postsecondary students with learning disabilities as compared to using a human reader or reading text silently, without assistance.

The notion that converting printed text to spoken language (e.g., books on tape, human readers, OCR/speech synthesis) might help students compensate for reading difficulties is suggested by a number of sources. First, this idea is rooted in the fields of both language development and learning disabilities which has long contended that students' comprehension of oral language both precedes and exceeds their comprehension of written text (e.g., Aaron

[2]Academic outcomes (e.g., GPA's, course completion rates), behavioral/affective changes, and cost effectiveness were examined in years two and three of this study.

& Phillips, 1986; Gough & Tunmer, 1986; Hoover & Gough, 1990; King & Rentel, 1981; Myklebust, 1973). However, it should be noted that the actual evidence is equivocal regarding the exact role of aurally presented text in the acquisition of reading, or its effect on reading comprehension as it is implemented in common classroom practices (e.g., listening to text, listening to text while reading, oral reading, "round robin" oral reading alternating with (presumed) aural listening). Research with children and adolescents has attributed differences in reading comprehension under silent reading conditions as opposed to listening (with or without accompanying text) to several factors including chronological age, grade level placement and/or reading level placement (Carver, 1990; Miller & Smith 1990, Sticht, Beck, Hauke, Kleiman & James, 1974; Sticht & James, 1984; Swalm, 1976), text difficulty (Lynch 1988), reading ability (Harker & Feldt, 1993; Miller & Smith, 1990) and content area (Harker & Feldt, 1993).

The idea that text to speech conversion may facilitate reading comprehension is also suggested from research in reading disabilities. Numerous studies have indicated that students with reading disabilities have a particularly difficult time with word recognition, especially phonological decoding skills (Bruck, 1988, 1993a; Holligan & Johnston, 1988; Lundberg, Frost & Petersen, 1988; Olson, 1985; Stanovich, 1988; Torgesen, 1994; Wagner & Torgesen, 1987). Such difficulties are likely to substantially impact reading comprehension, as phonological processing plays a crucial role in assigning meaning to text (Baron & Thurston, 1973; Davelaar, Coltheart, Besner & Johansson, 1978; Hawkins, Reicher, Rogers & Peterson, 1976; Meyer, Schvaneveldt & Ruddy, 1974; Perfetti & Hoganboam, 1975;

Rubenstein, Lewis & Rubenstein, 1971). Several researchers (Daneman & Carpenter, 1980; Lundberg & Leong, 1986; Perfetti, 1975; Swanson, 1992) have suggested that the problems experienced by children with learning disabilities in phonological processing negatively impact reading comprehension by "overtaxing" the immediate cognitive processing mechanism with the decoding task, so that energies are not available to be used by other mental processes necessary for comprehension.

Research has also indicated that "good readers" differ from "poor readers" (not necessarily "learning disabled readers") in the speed at which they can name words, with the discrepancy being stronger for unfamiliar words (Perfetti & Hoganboam, 1975). Along these lines, studies on populations of children (Bruck, 1988; Olson, 1985; Shankweiler, Liberman, Mark, Fowler & Fischer, 1979), and more recently with adults with learning disabilities (Bruck, 1993b), indicate that it is specifically those words which must be "sounded out" or translated into phonological representations before a meaning can be assigned (e.g., unfamiliar words, homophones) that give persons with learning disabilities the most difficulty. This is consistent with findings that "poor readers" have been found to rely heavily on initial letters, fail to notice or integrate medial and final sounds (Rayner & Hagelberg, 1975; Shankweiler & Liberman, 1972) and to be less efficient in articulating sound-spelling correspondences (Bruck, 1993a, 1993b; Jorm, 1977; Venezky, 1976).

Considering that the above literature indicates that many persons with learning disabilities have difficulty with the decoding process, and that this may in turn interfere with reading comprehension, the researchers hypothesized that OCR/speech synthesis might enhance reading comprehension by performing the decoding task for the student, thus allowing attention to be directed to the comprehension task. Further support for this assumption comes in light of literature indicating that individuals with reading disabilities often exhibit no apparent deficit in understanding spoken language (Aaron & Phillips, 1986; Gough & Tunmer, 1986). Specifically, it appeared that the use of an OCR/speech synthesis system would serve to circumvent difficulties in phonological processing by supplying the "names" of words out loud, thereby allowing the (presumably) superior listening comprehension skills to be applied to the task of assigning meaning to text.

The potential benefits of synthetic speech technology are also indicated by the actual use of the technology with individuals with learning disabilities. Several studies using speech synthesis with children with learning disabilities have suggested that it may be helpful in the remediation of reading (Elkind, 1993; Leong, in press, 1992; Lundberg, in press; Torgesen & Barker, in press) and spelling difficulties (Wise and Olson, 1992), as well as enhance writing performance (Higgins & Raskind, in press; Meyers, 1992; Raskind & Higgins, in press). Furthermore, as previously noted, a number of anecdotal reports from postsecondary learning disability support service programs contend that the OCR/speech synthesis systems are useful in helping postsecondary students compensate for reading disabilities (Brown, 1987; Bryant, Rivera & Warde, 1993; Raskind & Scott, 1993).

The purpose of this study was to determine whether the use of an OCR/speech synthesis system would enhance reading comprehension in postsecondary students with reading disabilities as compared to two alternative reading conditions: (1) another person reading text to the student; and (2) reading silently, without assistance. As previously discussed, the use of a human reader is a common support strategy used by postsecondary learning disability support service programs to help students compensate for reading disabilities (Adelman & Vogel, 1993; Mellard, 1994), and is also being utilized to accommodate learning disabled examinees on professional licensing exams outside the postsecondary setting as well as in the workplace (Grossman, 1994). The condition the authors have termed reading with "no assistance" is, of course, frequently used by students, and may be the result of the students' desire to work independently, lack of awareness regarding alternative strategies and/or the lack of availability of learning disability support services within the secondary program.

It is important to emphasize that the condition in which the text was read aloud by another person was not chosen for study because of a research or theoretical base (although some of the same literature which supports converting text to synthetic speech (e.g. oral language abilities presumed superior to written language abilities), also tends to support the efficacy of human readers), but rather because human readers are frequently utilized in postsecondary learning disability programs (Mellard, 1994; Shaw, McGuire & Brinkerhoff, 1994; Vogel & Adelman, 1993). Furthermore, it should be stressed that the three reading "conditions" were not employed as treatments aimed at determining the most effective instructional method for remediating reading comprehension problems. Although the focus of K-12 educators of students with learning disabilities is primarily directed toward remediating deficits, postsecondary learning disability support service providers (particularly in university settings) are most often concerned with providing compensatory strategies that enable students to bypass or circumvent the disability.

In an effort to determine the effectiveness of OCR/speech synthesis in compensating for reading disabilities, subjects were administered a test of reading comprehension (alternate forms) under three separate conditions: (1) reading the exam and questions silently with no assistance; (2) listening to a human reader read the paragraphs and questions; and (3) scanning the text into the computer using an OCR system and having the paragraphs and questions read aloud via the speech synthesis/screen review program. Based on the above described previous research, it was predicted that subjects would receive higher reading comprehension scores utilizing either the OCR/speech synthesis system or a human reader as compared to reading silently, without assistance. No prediction was made as to differences between the OCR/speech synthesis and human reader conditions.

METHOD

Subjects. Thirty-seven postsecondary students currently enrolled at California State University, Northridge (hereinafter CSUN) participated in the reading comprehension OCR/speech synthesis portion of the study. CSUN is a state university offering a full undergraduate program, as well as a graduate division which grants masters degrees in several disciplines. The population of students reflects the larger community in which the University is embedded; Northridge is a predominantly middle class, multi-ethnic suburb of Los Angeles located in the San Fernando Valley. Self-ratings on socioeconomic status of 1-5 (highest through lowest) were 1 = 1, 2 = 3, 3 = 23, 4 = 10, and 5 = 0. Ethnicity (self-declared) included 4 African-Americans, 5 Hispanics, 1 Asian-American and 27

Caucasians. Average age was 24.9. Mean IQ for the participants was 97 and mean reading comprehension was 88.0.

All subjects had been identified previously as having a learning disability by either the Office of Disabled Students Services at CSUN or at a previous institution (See Appendix A for the University's criteria for identification.) In addition, all participants showed a discrepancy of twelve or more standard score points between reading aptitude as measured by the Woodcock-Johnson Psycho-Educational Battery, Part II and reading achievement as measured by the Woodcock-Johnson Psycho-Educational Battery, Part I (Woodcock & Johnson, 1977), or reading achievement and IQ as measured by the Wechsler Adult Intelligence Scale-Revised (Wechsler, 1981). In a few cases where assessment was done at other institutions, alternative standardized tests of reading performance and aptitude were substituted to determine the specific disability in reading.

Equipment. The optical character recognition system (OCR) consisted of a Hewlett Packard Scanjet Arkenstone Reader and Arkenstone conversion software which scanned in text (pages from books in various fonts, typed or printed pages from a variety of sources such as computer printouts, typewriters, newspapers, xerox copies, etc.) and converted it into a WordPerfect 5.0 computer document. The conversion program was installed on an IBM-compatible 486 personal computer with 4 megabytes of random access memory.

Installed on the same personal computer was a "SoundProof®" internal board speech synthesis/screen review system Version 1.12 from HumanWare, Inc. This system highlighted each word as the speech synthesizer read it aloud. The volume, speed and pitch, as well as highlighted and contrasting background colors could be set to accommodate individual preferences. The user could read by word, sentence, line, paragraph or read continuously, stopping when necessary. The cursor could easily be manipulated to go back to previously read material, reread it and return to the previous position. The system could be operated using either a speaker or headphones.

Testing Materials. The silent reading comprehension section of the Formal Reading Inventory (FRI) (Wiederholt, 1986) was used to assess reading comprehension. This standardized test requires students to read a series of progressively more difficult paragraphs and give the "best" answer to five multiple-choice reading comprehension questions for each paragraph. The nature of the printed format allowed students to refer back to the paragraph or questions at any time.

Procedure. During the first session, students were trained on both pieces of equipment (OCR and speech synthesis/screen review programs) and shown how to make various adjustments to suit individual needs or preferences. They were then given practice/exploratory time as desired and encouraged to experiment with different speed, voice, and visual settings for different purposes. An instructor was available to answer any questions during the practice/exploratory period. Average training time was 45 minutes on both pieces of equipment; the range of practice time was from 10 to 110 minutes with an average of 23 minutes.

During the following three sessions, students took the reading comprehension test under each of the following conditions: (1) read the exam silently without assistance; (2) a human reader read the paragraphs and questions aloud; and (3) the student scanned the text into the computer using the optical character recognition system and employed the speech synthesis/screen review program to "read" the paragraphs and questions.

For each of the three administrations of the exam, one of four forms of the FRI was randomly assigned (A, B, C or D). As to the order in which the conditions were assigned to each subject, a list was prepared by randomly selecting (without replacement) one of the six possible permutations of the order of conditions (NA-RA-SS, NA-SS-RA, RA-NA-SS, RA-SS-NA, SS-RA-NA, SS-NA-RA) until a list of 50 items had been reached. Each subject was then simply given the next permutation on the list.

Under the silent reading condition it was possible to refer back to the paragraph or questions at any time since each page of the test booklet contained one paragraph along with its set of five questions. In order to equalize the conditions as far as possible, students were allowed to refer back to the paragraph as many times as they desired for the other two conditions as well. An additional instruction to this effect was given under each condition:

No Assistance: "It's OK to look back at the paragraph or the answers at any time."

Read Aloud: "It's OK to have me reread the paragraph or the answers at any time."

OCR/Speech Synthesis: "It's OK to go back and reread the paragraph or the answers at any time."

Basals and ceilings were established as per the protocol for the test (Wiederholt, 1986). No time limits were imposed for any of the conditions.

RESULTS

As to possible confounding variables, no significant differences were found for order of administration of the conditions $F(2, 108) = .111$, $p = .895$, or for forms of the exam administered $F(3, 107) = 1.306$, $p = .276$.

Preliminary data also indicated there was no appreciable effect across conditions. The ANOVA showed no significant differences in standard score means $F(2, 108) = .193$, $p = .825$. The lack of difference between means across conditions appeared to be largely due to the fact that the technology raised scores for some students but interfered with performance for others. Subject variability, therefore, exceeded between group variability. Any population of students with learning disabilities contains a diverse collection of difficulties with regard to reading comprehension, only some of which may be helped by the technology. For example, students with a visual processing difficulty may find the computer screen a less confusing medium than printed text, or, the reverse could be true. Further analysis is planned to examine individual subscores on standardized tests such as the WAIS-R, etc., in order to discover whether the "hits" and "misses" fit any particular profile of disability.

Notwithstanding what may be discovered by such future inquiry, a more global pattern was found which suggests what general effect the technology may have on reading comprehension.

[insert Figure 1 here]

When scores on the "No Assistance" condition were arranged from lowest to highest ("x's" in

Figure 1) and scores on the "OCR/Speech Synthesis" condition were plotted against them (dots in Figure 1), an inverse correlation emerged. (Scores on the "No Assistance" condition approximate a 45 degree slope while the "OCR/Speech Synthesis" condition proceed more-or-less horizontally.) The relationship is even clearer in Figure 2 where only differences between the scores were plotted.

[insert Figure 2 here]

The "No Assistance" scores are plotted along the "zero" axis; actual "No Assistance" scores (61, 68, 70 ... 116) appear at the bottom of the figure. "OCR/Speech Synthesis" scores appear as "dots" above or below the zero axis. The Pearson's correlation coefficient proved to be highly significant ($p > .001$). Stated simply, the greater the disability in reading comprehension, the more likely it was that the technology would assist students in compensating for their difficulties.

Figure 3 represents plottings for the "Read Aloud" condition. A similar, but weaker correlation was evident ($p > .01$).

[insert Figure 3 here]

DISCUSSION/IMPLICATIONS FOR PRACTICE

The fact that both the "Speech Synthesis" and "Read Aloud" conditions showed a similar pattern of influencing scores suggests that the addition of auditory input per se is responsible for the effect. Both "Read Aloud" and "OCR/Speech Synthesis" scores for less proficient readers were elevated as compared to the "No Assistance" (silent reading) condition, and depressed as compared to silent reading for proficient readers. The latter finding is consistent with Harker & Feldt (1993) who found that secondary level "poor" readers showed improved reading comprehension scores on the Iowa Test when given accompanying tape recorded versions of the text, while good readers did not benefit.

One line of research that may offer a possible explanation for the above findings comes from "shadowing" experiments reported in the cognitive psychology literature. Subjects are asked to silently read pairs of words while performing an interference task orally, such as counting out loud, repeating a word over and over or repeating words heard through headphones. Kleiman (1975) presented subjects with pairs of words, some of which were similar in sound while others were similar visually. He found that the interference of the oral task was greater for the word pairs similar in sound.

The interference effect has relevance to the current study because it introduces the possibility that the auditory information supplied by the assistive technology (or being read to) could affect more strongly those words which must be translated into phonological representations like Kleiman's pairs that were similar in sound. Therefore, one possible outcome of the current study could have been that those students who were struggling to "sound out" more words (e.g., due to unfamiliarity, sound similarity) would find the auditory input distracting more often than those who were recoding fewer words into phonological representations. However, if this had been the case, less proficient readers would have shown a decrease in performance using the technology as compared to proficient readers. Clearly, this was not consistent with the findings of the present study. Less proficient readers showed an increase in performance.

On the other hand, the auditory input supplied by the technology could allow less proficient readers to circumvent having to struggle with sounding out words altogether, producing the opposite effect. In this case, the less efficient decoders' performance would improve (given no other comprehension difficulties existed), while proficient readers' performance would either remain relatively unaffected or show a decrease due to some other variable. This is, in fact, what our study found in terms of decoding.

Having "explained" the increases shown by less proficient readers as due to the circumvention of interference (of the inefficient phonological decoding), how might one utilize an interference model to account for the decreases in performance experienced by the proficient readers? Beyond the interpretation of individual words, auditory interference tasks have also been shown to disrupt syntactic acceptability tasks. For example, the Kleiman study described above found that the interference effect was even greater on syntactic judgments than on the word pairs similar in sound. Further support for the notion that phonological coding is necessary for sentence comprehension also comes from another line of research which involves the inhibiting of the muscle movements of the speech mechanism during silent reading. These movements, called sub-vocalization, occur even though no sound is being emitted by subjects during silent reading, and are assumed to be the "sounding out" of the text, or conversion of it to some type of phonological code. Using biofeedback techniques, Hardyck & Petrinovich (1969, 1970) were able to teach subjects to control sub-vocalization movements of the larynx. Interestingly, their finding was that suppression of these muscle movements disrupted the comprehension of difficult, but not simple sentences.

Crowder (1982) interprets these findings as evidence that phonological coding may be utilized for purposes other than "sounding out" unfamiliar words. He suggests that phonological coding may act as a short-term memory buffer for syntactic processing at the sentence level as well.

The findings in the current study appear to confirm those hypotheses above which hold that phonological coding is necessary for the processing of at least some sentences. Proficient readers' scores were depressed using the equipment, and to a lesser degree when passages were read aloud. This tends to confirm that the auditory input provided an interference effect with syntactic processing, consistent with both Kleiman's findings for subjects who were asked to make fine judgments as to the syntactic acceptability of sentences, and with Hardyck and Petrinovich's finding that interference with phonological coding affects difficult, but not easy sentences. As the paragraphs presented in the present study increased in difficulty, so did the complexity of the syntax within the sentences. Subjects and verbs were ruthlessly separated by parentheticals, dependent clauses and the like. This may have depressed proficient readers' scores more than lower-scoring readers because the less proficient readers simply did not get through the test far enough to experience these tougher passages. In other words, the current data provides evidence suggesting that a kind of "ceiling" effect is in operation concerning the understanding of syntactically complex sentences when auditory presentation of the material is offered.

The assertion of previous researchers as to the relationship of sentence complexity and memory (short-term memory, working memory) is intriguing in light of the current data.

The contention is that the difficult sentences are disrupted by auditory interference because difficult sentences are longer. Phonological coding becomes necessary due to cognitive limits on short term memory (irrespective of sentence complexity?), as noted by Miller (1956) and others. The reader must hold the beginning of the sentence in memory longer with the slower, auditory presentation while attempting at the same time to process the end of the sentence. Speech synthesis technology offers a great opportunity to test the validity of this short term memory hypothesis since it allows for the speeding up of the auditory presentation of the text to the point where it would approach the rate of silently read text. A related line of research investigated compressed speech using a variable speed tape recorder with non-disabled readers. Although reading comprehension was superior with silent reading when the accompanying auditory input was at a normal rate of speech, comprehension became equal in both modalities when the rate of auditory presentation of the text approached that of silent reading (Carver, 1990; Sticht, Beck, Hauke, Kleiman, & James, 1974; Sticht & James, 1984).

A few of the students in the study (and many of the visually impaired students served by the Computer Access Lab at the University) have found that with practice they can accelerate the speech to levels much higher than any human reader could achieve, without losing intelligibility. As more data comes in concerning the use of the technology, it is possible that the level of interference in syntactic processing can be minimized by training students to assimilate faster presentations. The "ceiling," in effect, could be raised, so that those students who need the technology to decode the material could benefit even further with practice. (Of course, proficient readers can simply choose not to use the equipment if they find it interferes with their comprehension.)

The implications of the above findings for practical applications of the technology in a university setting appear to be relatively straightforward. The research supports recommending the use of OCR/speech synthesis technology for students with pronounced reading comprehension difficulties in managing the completion of reading requirements and other class assignments. It also appears to be suitable for testing purposes with less proficient readers when reading comprehension or understanding of a content area is being evaluated (e.g., course midterm or final exams, university-administered qualifying exams). If the subskill of phonological decoding is being tested, however, obviously the technology is not appropriate, since the data indicates OCR/speech synthesis allows students to circumvent the decoding process, the very skill being tested. It is equally clear from the data that the technology is not applicable for students who have already achieved a high level of proficiency in silent reading comprehension. The implication of this finding is that careful evaluation should be made of each students' silent reading comprehension before suggesting use of the technology. Ideally, a test of reading comprehension should be administered to the student under silent reading and OCR/speech synthesis conditions using alternate forms of the test. These results should be shared with the student so that he/she may make informed choices as to the use of and/or purchase of OCR/speech synthesis systems.

The importance of informing students of their actual performance is underscored by the fact that comprehension scores did <u>not</u> correlate well with students' affective responses to the equipment, i.e., those students who reported feeling more "comfortable" reading with

OCR/speech synthesis or believed they had done better when using it, were not necessarily the individuals who actually improved their performance. Perhaps some students were experiencing "discomfort" due to reaching new upper limits of performance, or conversely, believed they had "done well" because they had only completed relatively easy sections of the test, even though they were capable of achieving more. Although the authors do not wish to minimize the importance of developing feelings of comfort and enjoyment in the reading task, and acknowledge that that alone can be rationale enough for using the equipment, it is also important for each student to be as informed as possible as to the effect the assistive technology has on his or her performance. Critical decisions which can affect the entire course of a student's life, such as selecting the appropriate testing accommodations on a professional licensing exam, should be made with full knowledge of the effects of technology on performance when such information is available, especially considering that the students' internal responses to the technology were not always accurate estimates of the efficacy of the equipment.

LIMITATIONS/IMPLICATIONS FOR FUTURE RESEARCH

Of course, another explanation of the finding that auditory input disrupted sentence comprehension for proficient readers is that the population of "good" readers in this study is atypical. It should be recalled that what the authors are calling "proficient" readers may not have been comparable to the "good" readers in other studies on non-disabled populations. On the contrary, the subjects here were selected for this study precisely because they have a disability in reading comprehension. One criterion for selecting subjects depended on at least a 12 point discrepancy between their performance and what one might expect, given their intellectual potential. Although they may not have been as severely disabled as those struggling to sound out each word, a deficiency did exist in their comprehension of written text. It may be that they share a common disability, or a common way of compensating for it which is disrupted by auditory input. In any case, although suggestive, the data presented here must be considered less clearly supportive of any hypotheses concerning the scores of the proficient readers (including the hypothesized interference effect for simultaneous auditory presentation) since individual differences were great for this group, particularly under the "Read Aloud" condition.

The findings from this study, as well as others previously reported (Higgins & Raskind, in press; Raskind & Higgins, in press), indicate that any particular assistive technology can have differing effects on individuals with learning disabilities, depending on the level of disability, area of disability or specific deficit. It is hoped that since a great deal of diagnostic information on the subjects of the study is available to the researchers, the possibility of using assessment results to prescribe particular technological interventions can be explored.

Differences in the effectiveness of a particular technology across tasks has also been found. For example, the speech synthesis/screen review technology has been applied to the task of proofreading as well as reading comprehension with the finding that for the proofreading task, speech synthesis/screen review appeared to assist almost all subjects, not just below average readers or proofreaders (Raskind & Higgins, in press).

The study concentrated on an adult population in an academic setting. The reader is cautioned to avoid generalizing the efficacy values reported here to other chronological ages and grade levels or to other contexts, such as employment. Further research will be necessary to determine how effective the assistive use of OCR/speech synthesis can be with other age groups, and in other settings across the lifespan of persons with learning disabilities. It has already been pointed out that the study focused on compensatory effectiveness as opposed to instructional or remedial effect. Other researchers have reported, and will continue to report their findings concerning the use of OCR/speech synthesis in preventing, diagnosing, and remediating learning disabilities in children and adolescents. The authors hope, however, that the assistive use of technology will also be a topic of interest to researchers with both children and adults with learning disabilities.

Perhaps the most interesting areas for future research on the technology are being supplied by the students themselves. As mentioned earlier, there has been experimentation with speeding up and slowing down the input to fit task as well as individual cognitive processing needs. Additionally, as the authors continue gathering information on the use of the technology by the students, they are struck by the fact that compensatory effectiveness is not the only criteria by which students make the decision to use technology in general or a specific piece of assistive technology at a given time for a given purpose. Availability, convenience, comfort, the nature of the written material and time efficiency may all play a role in the use and exploration of the equipment. Analysis of the data currently being accumulated will hopefully yield a workable model of the decision-making process which will allow manufacturers and users to develop and extend the efficiency and applicability of technology to the needs of persons with learning disabilities.

Appendix A

ELIGIBILITY CRITERIA

I. Prior Verification

Prior verification may be used for eligibility to receive learning disability support providing that:

1. Documentation is submitted by a professional qualified to diagnose a learning disability (e.g., neurologist, educational psychologist, resource specialist, learning disability specialist)
2. Said documentation includes the testing/evaluation procedures and test results used to make a diagnosis of a learning disability.
3. Testing/evaluation results are dated no more than three years prior to the date of request for learning disability services.

II. Diagnostic Assessment

A. Significant intra-cognitive discrepancy(ies) (score greater than or equal to standard error of difference at .05 level) as measured by technically adequate standardized instruments of aptitude (e.g., Verbal IQ vs. Performance IQ Perceptual Organization vs. Verbal Comprehension on the Wechsler Adult Intelligence Scale-Revised). Students with learning disabilities characteristically display significant intracognitive [sic] scatter as compared to non-learning disabled students. Prior verification must meet the same criteria as outlined in Section II - Diagnostic Assessment

AND/OR B. Significant aptitude-achievement discrepancy(ies) (score greater than or equal to standard error of difference at .05 level), as measured by technically adequate, standardized instruments of aptitude (.e.g., Wechsler Adult Intelligence Scale-Revised, Woodcock-Johnson Psycho-Educational Battery, Part I) and achievement (e.g., Woodcock-Johnson Psycho-Educational Battery, Part II). This component refers to the difference between students' predicted ability levels and their assessed achievement levels (e.g., Reading Aptitude vs. Reading Achievement, Verbal Ability vs. Written Language Achievement, Math Aptitude vs. Math Achievement on the Woodcock-Johnson Psycho-Educational Battery, Parts I and II). Students with learning disabilities characteristically illustrate a significant aptitude-achievement discrepancy(ies).

AND C. At least one standard score in the average range of aptitude (greater than or equal to 90) as measured by technically adequate, standardized instruments of aptitude. This component is designed to assess students' intellectual/cognitive capacity in order to ensure that the student possesses the ability to achieve at the university level (e.g., Full Scale IQ, Verbal IQ or Performance IQ greater than or equal to 90 as measured by the Wechsler Adult Intelligence Scale-Revised).

D. An average or greater score (25th percentile or above) in at least one academic area as measured by technically adequate, standardized instruments of achievement. This component is designed to assess students' achievement levels in a number of academic areas in order to ensure they possess the skills necessary to achieve in a university setting (e.g., Reading Achievement, Math Achievement, Written Language Achievement as measured by the Woodcock-Johnson Psycho-Educational Batter, Part II).

To address the possibility that a learning disabled student may not be identified by standard diagnostic procedures, clinical judgment may be exercised in no more than ten percent (10%) of all students tested during an academic year. Recognizing that currently available assessment instruments may be biased when used with individuals who have cultural/language differences, the percentage of students who may be determined eligible on the basis of clinical judgment may be increased when the population of students tested includes large numbers of such students.

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Figure Captions

Figure 1: Standard Scores under No Assistance and Speech Synthesis Conditions

Figure 2: Difference Scores under No Assistance and Speech Synthesis Conditions

Figure 3: Difference Scores under No Assistance and Read Aloud Conditions

STANDARD SCORE
No Assistance vs. Speech Synthesis

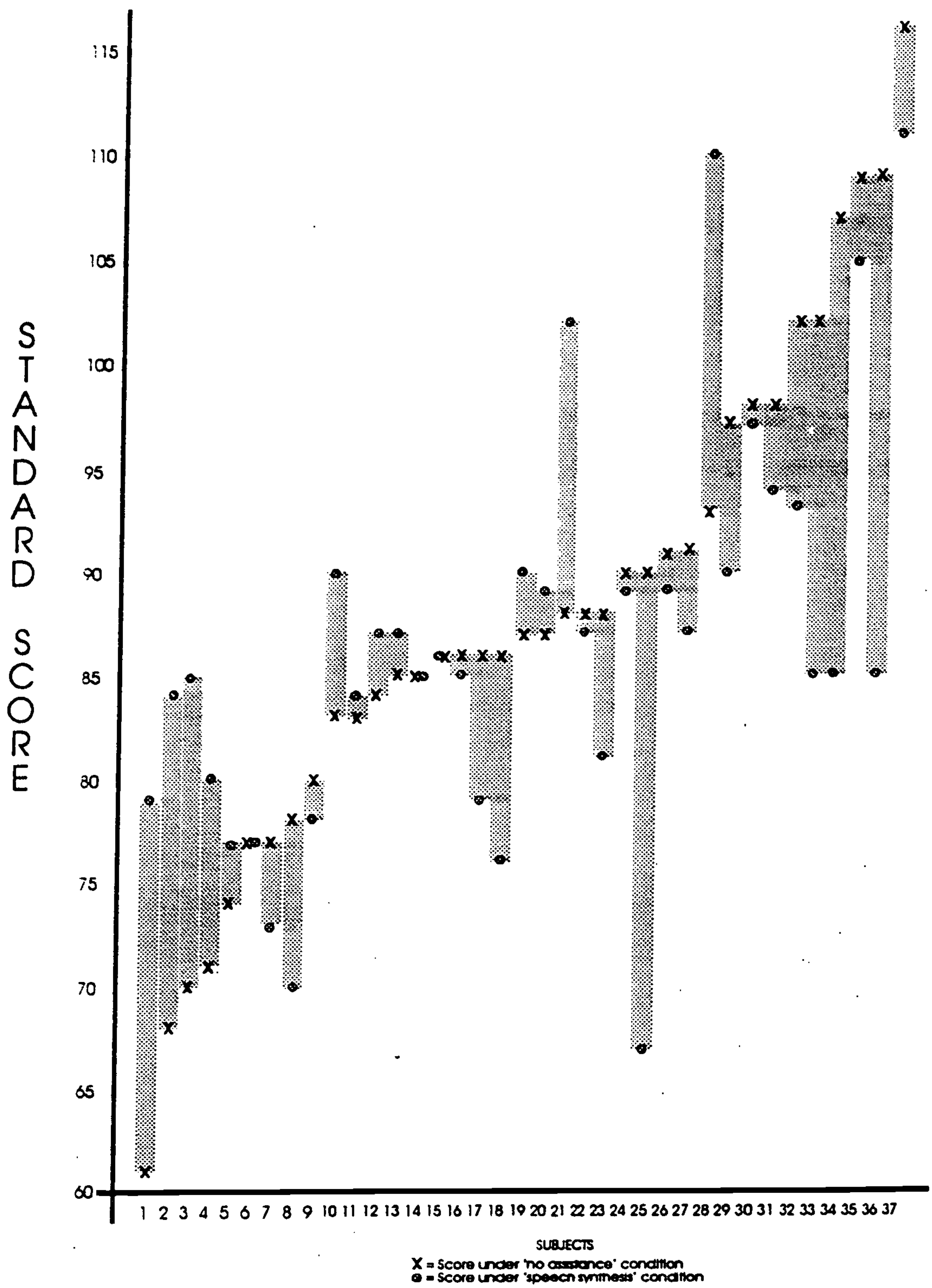

Fig. 1

DIFFERENCE SCORES
No Assistance vs. Speech Synthesis

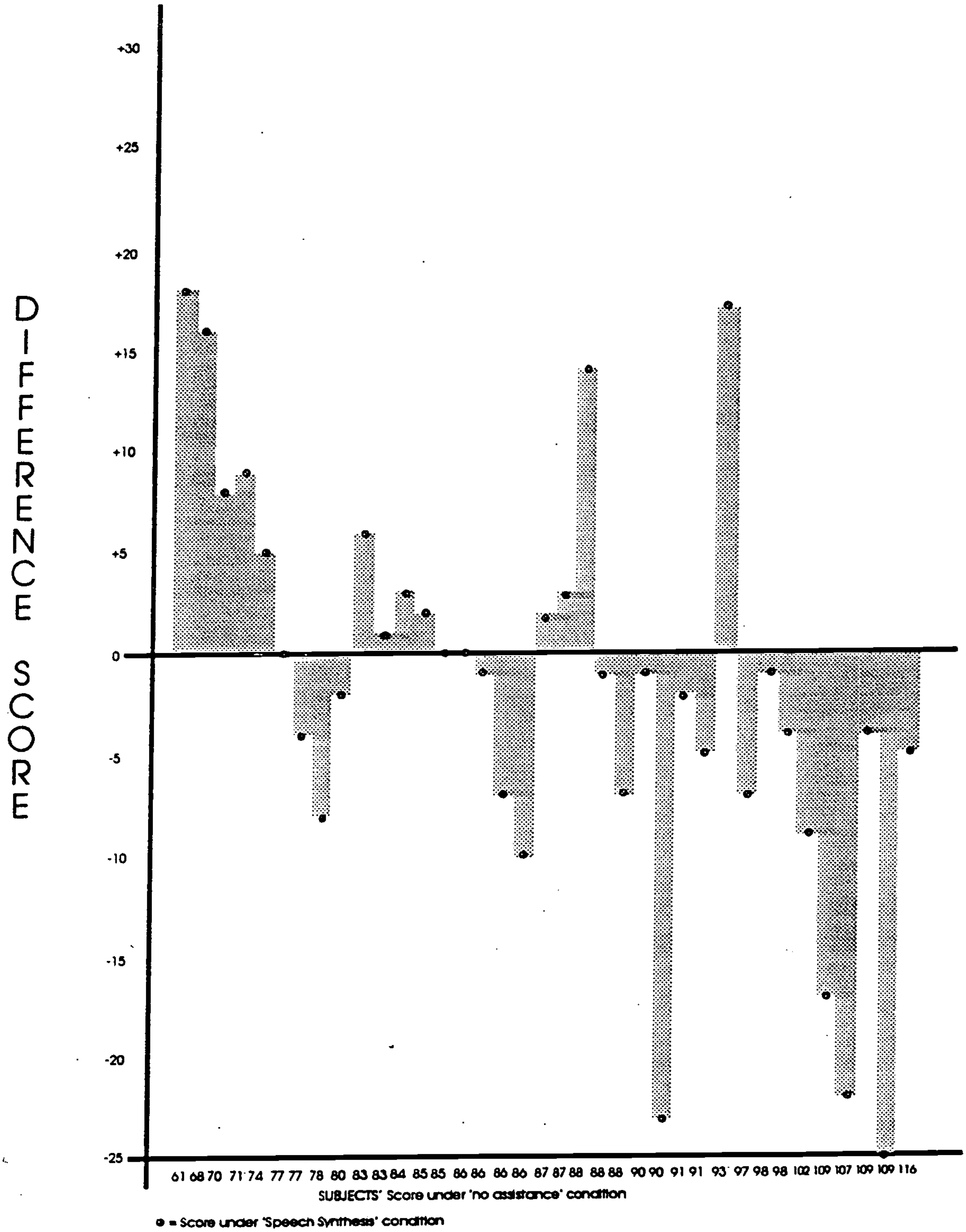

Fig. 2

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DIFFERENCE SCORES
No Assistance vs. Read Aloud

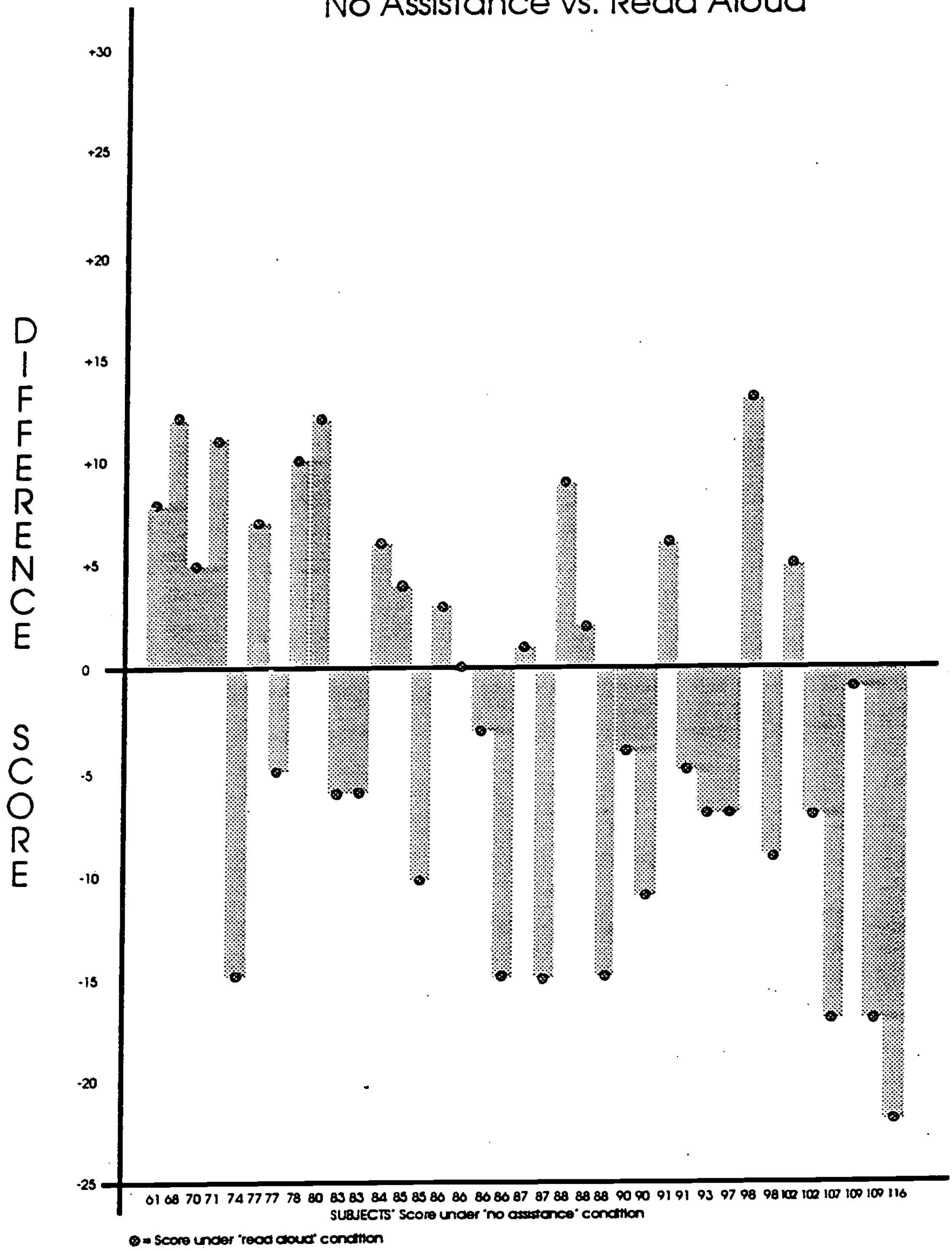

Fig. 3

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The Effects of Speech Synthesis on the Proofreading Efficiency of Postsecondary Students with Learning Disabilities

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Running head: SPEECH SYNTHESIS & PROOFREADING

Abstract

This study investigated the effects of speech synthesis on the proofreading efficiency of postsecondary students with learning disabilities. Subjects proofread self-generated written language samples under three conditions: (1) using a speech synthesis system that simultaneously highlighted and "spoke" words on a computer monitor, (2) having the text read aloud to them by another person, and (3) receiving no assistance. Results indicated that the use of the speech synthesis system enabled subjects to detect a significantly higher percentage of total errors than in either of the other two proofreading conditions. In addition to total errors, subjects were able to locate a significantly higher percentage of capitalization, spelling, usage and typographical errors under the speech synthesis condition. However, having the text read aloud by another person significantly outperformed the other conditions in finding "grammar-mechanical" errors. Results are discussed with regard to underlying reasons for the overall superior performance of the speech synthesis system and to the implications of speech synthesis as a compensatory writing aid for postsecondary students with learning disabilities.

Since 1985, the number of students with learning disabilities entering postsecondary institutions has grown faster than any other disability group, having increased from 15 percent to 25 of all college freshman who report disabilities (American Council on Education, HEATH Resource Center, 1992). In fact, according to Jane Jarrow (1987), Executive Director of the Association of Higher Education and Disability, individuals with learning disabilities are the "single largest contingent of students with disabilities being served on American campuses" (p. 46). While the exact number is difficult to determine (Vogel, 1993), extrapolation from government research (American Council on Education, HEATH Resource Center, 1992; National Center for Education Statistics, 1989) suggests that there are approximately 160,000 to 300,000 students with learning disabilities currently enrolled in postsecondary institutions across the nation. The number of students with learning disabilities is likely to remain high considering that there are over 100,000 students with learning disabilities exiting high school every year (Office of Special Education Programs, 1992) and that as many as 67% have plans for future education (White et al., 1982).

The tremendous influx of students with learning disabilities into postsecondary institutions has prompted the development of learning disability support service programs designed to promote academic retention and success (Beirne-Smith & Deck, 1989; Vogel, 1987, 1993). As research has indicated (e.g., Hughes & Smith, 1990; Vogel & Adelman, 1990), the academic performance of postsecondary students with learning disabilities is inferior to that of non-disabled peers and includes difficulties in reading, writing, speaking, listening and math (Hughes

& Smith, 1990; Morris & Leuenberger, 1990). One educational support service approach which has gained attention over the last several years is "assistive technology" (Brown, 1987; Collins, 1990; Mangrum & Strichart, 1988; Scheiber & Talpers, 1985; Vogel, 1987). Assistive technology (sometimes referred to as "auxiliary aids") for postsecondary students with learning disabilities includes such items as personal and laptop computers, word processors, tape recorders, speech synthesizers and electronic spell-checkers. These technologies are not used for the purpose of instruction, nor the remediation of deficits, but rather, to help students compensate for their difficulties. The technology may assist, augment, or supplement performance in a given area of disability, or may be utilized to "bypass" or circumvent specific deficits entirely (Raskind, 1994).

Although there has been a growing interest in the use of assistive technology with postsecondary students with learning disabilities, there is a paucity of controlled research that has formally investigated its efficacy. Indications on the benefits of assistive technology for postsecondary students with learning disabilities have been derived primarily from "testimonials", case studies, and anecdotal reports (e.g., Brown, 1987; Collins & Price, 1986; Raskind & Scott, 1993). Furthermore, the small number of controlled studies conducted on technology and postsecondary students with learning disabilities (Collins, 1990; Primus, 1990) have been limited to word processing. The lack of research in this area is especially surprising given the attention assistive technology has received with regard to other disability groups (e.g., Church & Glennen, 1992; Enders & Hall, 1990; Green & Brightman, 1990) and the attention technology has received as instructional/remedial tools for children with learning disabilities (e.g., Chiang, 1986; Johnson, Gersten & Carnine, 1987; Jones, Torgesen & Sexton, 1987; Lee, 1987; Torgesen, Waters, Cohen & Torgesen, 1988; Woodward & Carnine, 1988).

In an effort to address the lack of research directed toward assistive technology and postsecondary students with learning disabilities, the present study (part of a three-year study on the effects of assistive technology on postsecondary students with learning disabilities funded by the U.S. Department of Education, Fund for the Improvement of Postsecondary Education) investigated the effectiveness of speech synthesis (text-to-speech conversion) as a compensatory writing aid. Specifically, the study examined whether a speech synthesis/screen review system that simultaneously "spoke" and visually highlighted words on a computer screen would help alert students to errors in their writing. Written language was chosen because of the high incidence of difficulties in this area within the postsecondary learning disabled population. According to Blalock (1981), 80%-90% of adults with learning disabilities exhibit written language disorders. Researchers have found that postsecondary students with learning disabilities have difficulties in the areas of grammar, punctuation, spelling, organization and coherence (Gregg, 1983; Gregg & Hoy, 1989; Hughes & Smith, 1990; Morris & Leuenberger, 1990; Vogel, 1985; Vogel & Moran, 1982). Such difficulties will result in considerable hardship, as writing skills are likely to be heavily tapped in most postsecondary programs. Many postsecondary institutions have a writing proficiency requirement which must be satisfied before graduation. Additionally, students must contend with the writing required in mandatory English courses, or for that matter, any classes requiring term papers and essay exams.

The importance of helping postsecondary students with learning disabilities develop proofreading abilities *per se* as a means to improve the quality of their writing has been stressed by a number of authors (e.g., Adelman, O'Connell, Konrad & Vogel, 1993; Vogel, 1987). Identifying errors (or proofreading) is a key element in the revision process (MacArthur, Graham, & Schwartz, 1991). It is an essential step for correcting mistakes, and ultimately enhancing the quality of written language. Although the ability to locate errors in no way ensures the ability to appropriately correct them, failure to initially recognize errors, will inevitably hinder the revision process.

The notion that speech synthesis might help with the proofreading process is suggested by multiple sources. Historically, multisensory approaches have been cited in the literature (although research results on their efficacy are equivocal, see Myers & Hammill, 1982) as a means to improve the academic difficulties (i.e., reading, spelling, penmanship) of students with learning disabilities (Fernald, 1943; Gillingham & Stillman, 1968; Heckleman, 1969). Specifically related to writing, Johnson and Myklebust (1967) recommended that a child with a learning disability be taught awareness of errors in his writing by "reading it aloud very slowly, checking word by word that he says exactly what is written" (p. 230). The authors present a series of related "auditory-visual integration" exercises to improve awareness of errors. Similarly, Alley and Deshler (1979, p.128) suggest that students with learning disabilities listen to their own writings by having the teacher read it back to them, or by reading passages into a tape recorder and listening to it as a means to teach recognition of writing problems. More recently, Espin and Sindelar (1988) report research results indicating that sixth- through eighth-grade students with learning disabilities were able to identify significantly more errors of punctuation, grammar and syntax by listening to written passages and sentences (via a tape recorder), as compared to simply reading the text.

Studies investigating the effects of speech synthesis on the writing process also support the idea that this technology may have potential benefits for enhancing the proofreading efficiency of students with learning disabilities. For example, Rosegrant (1986) found that students using "talking" word processors, as compared to students using standard word processors, made more revisions and produced texts that were longer and higher in quality. Similarly, Borgh and Dickson (1992) illustrated that the use of a speech synthesizer led to increased levels of editing and suggested that the "spoken feedback may have fostered and awareness of the need to edit" (p. 238).

Indications regarding the possible benefits of speech synthesis have also been derived from the direct use of the technology with individuals with learning disabilities. Several studies utilizing speech synthesis with children with learning disabilities have suggested that it may be helpful in improving reading (Leong, 1992; Olson & Wise, 1992), spelling (Wise & Olson, 1992) and writing performance (Myers, 1992). Additionally, a number of anecdotal reports and case studies have emerged from postsecondary learning disability support service programs suggesting that the use of speech synthesis can enhance the quality of written language produced by postsecondary students with learning disabilities (Brown, 1987; Lees, 1985; Norris & Graef, 1990; Raskind & Scott, 1993).

Over the last several years many postsecondary learning disability support service programs have begun utilizing speech synthesis systems in an effort to help students compensate for difficulties in writing (Brown, 1987; Raskind & Scott, 1993; Shaw, McGuire, & Brinkerhoff, 1994). This interest in speech synthesis is probably based upon (in some part) the literature discussed above which suggests that listening to written passages may help persons with learning disabilities identify errors, and ultimately, enhance the quality of their writing. Interest may also have been fueled by recent developments in synthesized speech technology which have resulted in vast improvements in speech quality, accuracy, intelligibility and affordability, as well as the introduction of a number of new speech synthesis systems (some specifically for learning disabilities) into the commercial marketplace. Additionally, postsecondary learning disability programs have begun to seek alternative support service strategies, including the use of assistive technology, to meet the increasing financial and personnel demands of serving the rising number of postsecondary students with learning disabilities (Vogel, 1987).[1]

It should be noted, that in addition to merely converting computer text to speech, several of the speech synthesis/screen review systems now being utilized by postsecondary learning disability support service programs (including the one used in this study) have the ability to simultaneously visually highlight words as they are spoken. It appeared to the researchers that this feature might be an advantage over simply listening to the text (whether or not an attempt is made to visually follow the text). The isolation of individual words on the computer monitor by means of a block cursor might serve to "focus" the student on specific words and ensure that the word being read, is in fact the one being spoken. Failure to match the visual and auditory input might serve to undermine the proofreader's ability to detect a lack of agreement between the way the text actually appears, and the way the writer/proofreader intended it to be. Although not related directly to the task of proofreading, several authors have in fact suggested that the visual isolation of words on a display (referred to as "text-windowing") may enhance the ability of reading disabled students to attend to individual words (Jarvella & Lundberg, 1989; Lundberg & Leong, 1986).

The purpose of this study was to determine whether the use of a speech synthesis/screen review system is a viable strategy for enabling postsecondary students with learning disabilities to locate more errors in self-generated written language samples as compared to two alternative proofreading conditions-- 1) another person reading to them, and 2) no assistance. The use of a human reader is a common support service strategy among postsecondary learning disability support service programs (Adelman & Vogel, 1993; Mangrum & Strichart, 1988; Mellard, 1994). Reading aloud is also a compensatory strategy that is currently being utilized to accommodate learning disabled examinees on professional licensing exams outside the university setting (Grossman, 1994). Receiving "no assistance" is a condition which may be the result of the student's desire to work independently, lack of awareness regarding alternative strategies and/or the lack of availability of learning disability support services within the postsecondary program.

It is important to emphasize that the read aloud condition was not chosen because of a research or theoretical basis suggesting that it may be viable proofreading strategy (at the same time not dismissing the idea that such bases may exist), but rather, because this condition is being utilized at an ever increasing level by postsecondary learning disability support service programs. It should also be stressed that the three proofreading conditions were not employed as "treatments" aimed at determining the most effective means of teaching proofreading skills. Rather, the intent was to compare the compensatory effectiveness of these conditions. Although the focus of K-12 educators of students with learning disabilities is primarily directed toward remediating skill deficits, postsecondary learning disability support service providers are most often concerned (particularly in university settings) with providing strategies to enable students to bypass or circumvent the disability.

In an effort to determine the compensatory effectiveness of speech synthesis as a proofreading strategy as compared to receiving no assistance or being read aloud to, subjects proofread an actual essay they had written. During the first session, participants generated a "first draft" of a three to five typewritten-page composition on a topic of their choice. Essays were divided into thirds, and during a second session, subjects proofread the entire essay, one third of which was proofread under each of the above conditions. It was predicted that subjects would find more written language errors utilizing the speech synthesis system, as compared to the other two conditions, and that more errors would be found under the "read aloud" condition as compared to the "no assistance" condition.

METHOD

Subjects

Subjects were 33 (19 male; 14 female) students with learning disabilities registered with the Learning Disability Program of the Office of Disabled Student Services at California State

University, Northridge (CSUN). The sample was selected from a total population of 305 students identified as "learning disabled" under the criteria specified by the Chancellor's Office of the California State University (CSU) system. These criteria include a) significant intra-cognitive discrepancy(ies), and/or b) significant aptitude achievement discrepancy(ies), and c) at least one standard score in the average range of aptitude (greater than or equal to 90), and d) an average or greater score (25th percentile or above) in at least one academic area. CSU criteria are used in conjunction with a systemwide definition of learning disabilities adapted from the National Joint Committee on Learning Disabilities (Hammill, Leigh, McNutt & Larsen, 1981). Subjects in this study also illustrated a discrepancy of 12 or more standard score points between language achievement as measured by the Woodcock-Johnson Psycho-Educational Battery, Part II and written language aptitude as measured by the Woodcock-Johnson Psycho-Educational Battery, Part I (Woodcock & Johnson, 1977), or written language achievement and IQ as measured by the Wechsler Adult Intelligence Scale-Revised (Wechsler, 1981).

Subjects' ranged in age from 19 to 37 at the time the writing sample was generated (with a mean age of 24.9). Diagnostic test results were gathered from Learning Disability Program files. All test results had been derived from testing within three years of subjects' acceptance into the Program. IQ scores (Full Scale) ranged from 88 to 116 with a mean of 101. Writing achievement scores were derived from the Woodcock-Johnson Psycho-Educational Battery, Part II. Written language achievement scores ranged from 72 to 108 with a mean of 86.

Subjects were predominantly "white and middle class." According to University records, twenty-five were identified as Caucasian, four as Hispanic, three as African-American and one as Asian-American. Thirty-one of the students reported that they were in the "middle" or "upper-middle" socio-economic class, one Hispanic student identified himself in the "lower" socio-economic class and one Caucasian student reported that he was in the "upper" class.

Technology

A "SoundProof" speech synthesis system (PulseData, Inc.; Version 1.00) was used in conjunction with an IBM compatible 386 computer with 4mg RAM and a VGA color monitor. The system consisted of a "KeyNote Gold" internal speech half-card and screen reading software which enabled subjects to select text on the computer screen and hear the words spoken (via the synthesizer) as they were simultaneously highlighted. A Sony SRS-27 external speaker was plugged into the speech card. The system ran at the same time as the chosen application program-- a word processing program (WordPerfect 5.0). Review functions were controlled at the computer's keyboard.

It was possible to review text by word, line, sentence or paragraph. The mode was selected by pressing "W", "L", "S", or "P" keys respectively. The current, previous, or next (relative to the position of the cursor) word, line, sentence, or paragraph could be read/spoken by pressing the ↓, ←, → keys respectively. Selected text could also be spoken (and simultaneously highlighted) by pressing the space bar to start/stop speaking. Silent navigation of the cursor was accomplished by pressing Shift- arrow keys. The screen background was light blue, characters were dark gray and words were highlighted by a white block cursor (as the default setting). Students could modify both background and character colors of the highlighted text for maximum contrast and readability. The system also allowed the user to control the rate of speech, volume and pitch.

Methodology for Determining Errors and Error Categories

The authors were interested in assessing the effectiveness of the speech synthesis system in as naturalistic a setting as possible. Although standardized tests exist that contain a section designed to assess proofreading, or in which knowledge of the rules of grammar, punctuation, etc. are assessed via a proofreading task, the manner in which these tests are derived render them contextually quite different from the "real-life" proofreading situations in which students must actually perform. Typically on these standardized tests, a well-constructed passage from a piece of literature is selected and a discrete number of errors is inserted into the text. This differs from the real life situations, first of all because these "perfect" passages, composed by veteran professional writers, are unlikely to resemble the real written language samples of inexperienced undergraduates and even less likely to reflect the writing that might be generated by students with a variety of learning disabilities. Sheer numbers of errors per essay, in some cases, would preclude comparability of the task to the real life situation faced by a learning disabled student in proofreading his or her work. (The range of errors in the present sample was from as few as 20 to as many as 200 errors in a single essay.)

Second, the types of errors which are inserted into these passages are designed to test knowledge of specific rules of grammar, spelling, punctuation and the like. Therefore, they are usually clear-cut examples of rule violations which have a single, unambiguous, multiple choice "right" answer. Real life errors, on the other hand, are frequently not nearly so clear cut as to which rule might apply and often have more than one solution for "fixing" the problem.

Compare the two passages below, one from a standardized test (Test of Written Language, Hammill & Larsen, 1978) and one from a students' essay.

(1) Betty lives on oak road.

(2) DaD caME hoME LaTE LasT NiGhT aND MoM GoT sick aND TiRED oF iT.

Third, the standards by which the above "naturalistic" sample may be judged would be expected to vary considerably if evaluated by a third grade teacher, a professor at a university, or an editor of a professional journal. While the professional editor would certainly disapprove of the cavalier use of upper and lower case, the third grade teacher may choose to ignore all capitalization difficulties, as well might a college professor accustomed to deciphering a variety of scribbled essay exams over the years. It was not known in advance by the researchers to what standard the students in the investigation were being held. The authors, consequently, were just as interested in the types of errors that "counted" to the intended audience (the actual readers of students' work product), as they were in the discrete number of errors upon which editors, teachers and professors might agree for the purposes of constructing and "airtight" and reliable reading for a standardized test item.

Therefore, while acknowledging that reliability across settings may suffer slightly by choosing not to use a pre-standardized test, gains in the validity of the findings more than compensated in the view of the researchers. To establish the types of errors that would be important to actual readers of postsecondary students' compositions, the following procedure was used:

1. A sample of seven essays written by students with learning disabilities (during the

course of study at CSUN) were proofread by a panel composed of the researchers, a doctoral level specialist in learning disabilities (responsible for assessment and identification of students with learning disabilities at the University) and two graduate students in English Composition who were readers for the University's Upper Division Written Proficiency Exam. Each of the five panelists read essays, circling errors and indicating in the margin the nature of the error in a brief description (e.g., "needs quotation marks," "verb-tense," "subject-verb agreement," "no cap," etc.).

2. Upon conferring on each essay, the panelists rapidly recognized a few "clear" categories of errors over which there was little variation on terms used to describe the error. These were later labelled "Capitalization," "Punctuation" and "Spelling."

3. Next, a group of errors involving the usage of individual words was examined. These included errors of both denotative and connotative meaning of the words. The panel labelled this category "Usage." At a later stage, errors in meaning that involved idioms and figures of speech were added to the category.

4. Next, a set of intra- and intersentential syntax errors was identified by the panel. These included subject/verb agreement, verb tense agreement, pronoun agreement (as to both number and person), etc. This category was labelled "Grammar-Mechanical."

5. Next, a category was identified which contained errors described as "fragment,"

"sentence fragment," "incomplete sentence," and "run-on sentence." This category was labelled "Grammar/Global."

6. A category was then identified which included errors labelled "typo," "spacing," "space," "two spaces between sentences," etc. This category was labelled "Typographical."

7. Next, a category was examined which included the following descriptions: "misplaced sentence," "sentence out of order," "paragraph," "¶," "different topic," "sentence sequence," "required paragraph," "new paragraph needed," and "sequencing." This category was initially labelled "Organization."

A category was also identified which included descriptions of errors that did not involve the use of language so much as underlying content, content organization or both. It contained errors in sentences that were grammatically correct, but were unclear, illogical or highly repetitive in terms of content. For example,

"Animals are squirrels."

"In other words, saying was his way."

"Then I raced home before that."

"Don't horn the diapers."

"So the moral is generations."

"Squirrels are fun to raise. Squirrels make enjoyable pets. Squirrels need a lot of attention and care. However, squirrels can be affectionate pets."

"The book was nice. I like it. It was easy to read. It was a good story to read."

Such passages included the following marginal descriptions: "unintelligible," "not clear," "incoherent," "coherence," "doesn't make sense," "meaning," "inconsistent," "illogical," "redundant," "repetitive," "repeating himself," "not clear," "clarity," "not sure what he means here," "doesn't support argument" and "poor example." The panel considered labelling the category "Content" or "Cognitive Organization Errors." There were few errors made in either this or the above category "Organization." Furthermore, some errors were ambiguous and difficult to classify as either "content" or "organization" problems. The panel decided to combine these two categories and settled on "Content/Organization" as the most descriptive phrase for the category.

8. Finally, a category entitled "Literary Style" was identified. Marginal descriptions included comments such as "padding," "metaphor," "mixed metaphor," "weak analogy," "slang" and "language inappropriate for audience." The comments accompanied sentences like the following:

"Her hair was greasy like a dog face."

"Nucular energy smiled at this."

"Parking on campus sucks."

"He dissed me whith that look."

"So my mom goes Why? So I go Whatever, mom and I left."

Thus, the nine categories generated were, to some degree, arbitrary, but were based on the panel's past experience in correcting college-level expository writing of learning disabled as well as non-disabled populations, knowledge of the University's English Composition curriculum and acquaintance with postsecondary level standards for written language. While this informal methodology for generating categories could easily be applied to other situations, the actual names and numbers of categories reported here should be used with caution across settings. As noted earlier, expectations for types of errors will vary across grade levels. Also, non-academic settings (e.g., a job training program) will have a different standard to which participants should be expected to perform. Finally, the categories may not generalize well for purposes other than research, such as instruction or remediation, since they tend to accentuate error detection over other goals for improving writing (e.g., revision, planning, fluency).

The above process resulted in the following nine categories which were subsequently used to score the essays:

1) Capitalization (omissions of capital letters at the beginning of a sentence, inappropriate intra-word capitalization, incorrect initial capital)
2) Punctuation (omitted or incorrect punctuation)
3) Spelling (misspelled words including substitution of a homonym)

4) Usage (errors of connotative or denotative meaning, incorrect use of idiom and figures of speech, etc.)

5) Grammar-Mechanical (errors of subject/verb agreement, tense, required personal pronoun, omitted article, etc.)

6) Grammar-Global (run on sentences, sentence fragments)

7) Typographical ("non-linguistic" typographical errors made during input of handwritten essays into the computer, or by subject during word processing)

8) Content/Organization (errors involving gross semantic confusions, logical or categorical content repetition, incoherent phrases, required paragraphs [as in direct quotation], misplaced sentences, etc.)

9) Style (errors such as mixed metaphors, inappropriate vocabulary for audience, excessive noun repetition, etc.)

Procedures

Writing samples. During the first session, subjects were asked to generate an essay of three to five typewritten pages on a topic of their choice. They were free to invent a topic or choose from a list of six topics preselected by the researchers. Preselected topics were taken from Select-a-Story (Learning Works, Inc., 1989) and consisted of such subjects as "important life events," "pick-a-proverb," "controversial issues," "life-shapers" and "prized possessions." All subjects were able to generate the essay.

Subjects were given the choice of writing by hand or using a word processing program (without spell-checking) to generate the essay. All handwritten essays were converted to word processing documents by staff and were entered precisely as they appeared in the handwritten document, including all errors (e.g., capitalization, punctuation, spelling, grammar). There were no time limits imposed on the subjects for generating the essay. They were allowed to make only a "first draft." These writing sessions were conducted in a private room with the subject and a researcher present.

Each document was subsequently divided into three equal parts. Within the next two weeks, subjects returned for a second session to proofread and locate errors in their essays under three separate conditions: (1) using the speech synthesis/screen review system (SS); (2) having the text read aloud by a human reader (RA); and (3) with no assistance (NA)-- proofreading the "hard-copy" independently. No time constraints were place on the subjects for any of these conditions. One-third of each subject's essay was proofread under one of the three conditions. All proofreading strategies were conducted during the same visit (i.e., the entire essay was read at a sitting). In order to control for any possible effects from the order of the proofreading condition, the order of the conditions was randomly assigned as to the six possible permutations (SS-RA-NA, SS-NA-RA, RA-NA-SS, RA-SS-NA, NA-SS-RA, RA-NA-SS).

Proofreading conditions. Each subject had received training in the use of the speech synthesis/screen review system prior to generating the writing samples. Training took approximately 15 to 20 minutes and all subjects were competent in the use of the system upon completion. Under the *speech synthesis* condition, subjects were instructed to proofread the essay using the speech synthesis system and to locate errors in punctuation, capitalization, grammar and spelling. In addition, they were told to look for run-on sentences, incomplete sentences and to modify "anything that doesn't make sense, belong or fit." Major changes to content were discouraged and subjects were asked to avoid crossing out or rewriting entire sentences or paragraphs. Rather, they were encouraged to add, delete or "change a few words." The idea was to change what they had written, rather than writing something entirely new.[2]

Corrections/changes were made on a hard copy of the text placed on the desk adjacent to the computer. Corrections were marked by: (a) adding, deleting, or changing letters, words, punctuation or capitalization; (b) indicating spelling errors by circling the word, marking it with "SP" or rewriting it; and (c) drawing arrows between words, phrases, sentences or paragraphs in order to reorganize. Subjects were free to use the speech synthesis system in any mode (i.e., word, line, sentence, paragraph, word to word) they preferred. Subjects were given a brief review of the system (2 to 3 minutes) to ensure competence in all operational procedures. All subjects used the system without difficulty. Sessions were conducted in a private room with only the subject and a member of the research team present.

In the *read aloud* condition, the reader (a member of the research team) read another third of the text out loud to the subject, sentence-by-sentence, refraining from providing any paralinguistic or kinesic cues (e.g., change in tone of voice, facial expressions) which might alert the user to errors. (Reading in this "constrained" manner is often requested by professors at CSUN.) The reader sat alongside the subject at a desk. Subjects could follow along on the hard copy if they wished. Subjects could also request that passages, or the entire text, be read as many times as they felt necessary. The subject was given instructions on the kinds of errors to find (as in the SS condition) and instructed to indicate/mark errors on the hard copy in the same manner as described in the *speech synthesis* condition. The *read aloud* condition was also conducted in a private room with only the reader and subject present.

In the *no assistance* condition, subjects worked independently, reviewing a third of their essay from a hard copy. They were given the same instructions as in the other two conditions, and again asked to make corrections/changes on the paper. They were not given restrictions on the kind of strategy to employ (e.g., read aloud, read backward) and were free to choose their own method of proofreading. As in the other two conditions, this condition was conducted in a private room with one of the investigators present.

Scoring Errors/Data Analysis

Four raters marked errors in all thirty-three essays, one researcher and three graduate students in written composition who had been trained to proficiency on the nine-category system described above. Interrater reliability was established for total number of errors found (.91) and category placement (.95). Additionally, interrater reliability was established for each of the error categories including: capitalization (1.00), punctuation (.96), spelling (1.00), usage (.90), grammar/mechanical (.95), grammar/global (.90), typographical (.97), content/organization (.90) and style (.88).

The total number of errors found by the subjects was divided by the number of errors found by the raters. This resulted in the percentage of total errors found by the subjects for each condition. The percentage of errors found was also calculated for each of the nine error categories.

Data were analyzed to determine differences in proofreading efficiency between each of the three conditions using a two-sample binomial test of proportion (Siegel, 1956). (This procedure was used rather than t-tests because proportions [percentages] rather than means of standard scores were being compared across subjects.) Paired comparisons were made for all conditions (SS-RA, SS-NA, RA-NA).

RESULTS

As predicted, results indicated that under the *speech synthesis* condition subjects found significantly more of the total errors (35.5%) than in either the *read aloud* condition (32%), $p<.04$, or the *no assistance* condition (25.0%), $p<.00005$. The difference between the *read aloud* condition and the *no assistance* condition was also significant, $p<.0001$. These results are presented in Table 1 and Table 2.

Insert Table 1 about here

Insert Table 2 about here

In addition to overall errors, differences between the conditions were also analyzed by the specific category of error (e.g., punctuation, grammar, content/organization). In the categories of capitalization and usage, subjects found a higher percentage of errors using the speech synthesis system (33%, 33% respectively) as compared to both the *read aloud* (18%, 6% respectively) and *no assistance* (19%, 17% respectively) conditions. These differences were statistically significant (capitalization, $p<.0005$; usage, $p<.0002$; for the RA condition; and capitalization, $p<.0009$; usage, $p<.04$; for the NA condition). Significant differences between the *speech synthesis* and *no assistance* condition (in favor of the SS condition) were also found for spelling (48% vs. 33%), $p<.00005$, and typographical (61% vs. 40%), $p<.04$, errors. A higher percentage of spelling and typographical errors were also found under the *speech synthesis* condition when compared with the *read aloud* condition, but these differences were not statistically significant. More errors of punctuation, grammar-global and style were also found using *speech synthesis* as opposed to the other two conditions, but again, these differences did not reach significance.

Under the *read aloud* condition, significantly more grammar-mechanical errors (35%) were found as compared to both the *speech synthesis* (22%), $p<.004$ and *no assistance* condition (20%), $p<.0009$. Additionally, significantly more spelling errors (45% vs. 33%) were found under the *read aloud* condition as compared to the *no assistance* condition. The *no assistance* condition outperformed the *read aloud* condition in usage errors, (but not the SS condition) at a statistically significant level (17% vs. 6%), $p<.04$. More errors of content/organization were also found under the *no assistance* condition than the other two conditions, but these differences were not statistically significant. These results are summarized in Table 3 and Table 4.

Insert Table 3 about here

Insert Table 4 about here

Although not directly related to the research question, it is interesting to note the frequency of specific kinds of errors and the extent to which they were located. The highest number of errors were those of spelling, with a combined total of 1,357 for all subjects. Spelling errors accounted for 39.9% (1,357/3,403) of all errors made. In contrast, only 85 stylistic errors were made accounting for only 2.5% of all errors.

The total number of errors found (for all conditions combined) was 1,047, or 30.8% of the total number of errors made (3,403). The highest number of errors found were those of spelling, with 567 being found out of a total of 1,047 (total errors found). This translates to 54.2% of total spelling errors found. Alternatively, only 10 content/organizational errors were found, accounting for a mere 1.0% of the total. The total number of errors for each category, made and found by subjects is summarized in Table 5.

Insert Table 5 about here

DISCUSSION

The results of this study indicate that postsecondary students with learning disabilities are able to locate a greater number of errors in self-generated written language samples using a speech synthesis/screen review system as compared to having the text read aloud by a reader or working without assistance (proofreading the "hard-copy" independently). However, it is important to stress that although the difference between the *speech synthesis* and *read aloud* condition was statistically significant, the difference was only 3.5% (SS = 35.5%, RA = 32%), (while the difference between *speech synthesis* and the *no assistance* condition was 10.5%). The use of a speech synthesis system also outperformed the other two proofreading conditions in seven out of nine categories of written language errors-- four at a statistically significant level.

These results are consistent with anecdotal reports and "clinical observations" (e.g., Brown, 1987; Lees, 1985; Norris & Graef, 1990;) which suggest that speech synthesis can enhance the quality of writing produced by postsecondary students with learning disabilities. Similarly, these results are supportive of others (Alley & Deshler, 1979; Johnson & Myklebust, 1967; Espin & Sindelar, 1988) who have suggested that listening to written language passages may be helpful in identifying errors. However, in this study, computerized speech, rather than a human reader (or tape recording) was found to be the most efficacious.

The precise reason for the enhanced proofreading accuracy using the speech synthesis system is difficult to determine. However, there are a number of possible explanations. First of all, the speech synthesis system reads text exactly as it appears. In contrast, subjects during the *no assistance* condition (as with readers in general) may have tended to read the text the way they thought it should be (Smith, 1978), rather than the way it actually was. Consequently, the "mismatch" between what subjects heard via the synthesizer and what they thought should be there, may have alerted them to errors. Any "mismatch" may have been accentuated by the fact that the speech synthesis system simultaneously highlighted individual words as they were spoken. (This may have helped focus subjects' attention and made them more sensitive to any mismatch.) Although the *read aloud* condition also enabled subjects to hear the text precisely as it was written, it did not provide the opportunity to have the words simultaneously highlighted. This may explain why the *read aloud* condition outperformed the *no assistance*, but not the *speech synthesis* condition.

It is also possible that the synthesizer simply provided the decoding necessary to access the print (essay). The task of proofreading (by definition) requires the reader to decode text. As the majority of the subjects also illustrated reading difficulties (as indicated by diagnostic records), the presentation of the text through speech may have provided them with an opportunity to directly access the text without preoccupation with decoding-- a task which may have drawn them away from their "error search." Similarly, free from having to decode, subjects may have spent more time in attempting to locate errors. Wise and Olson (1992) found that "spelling disabled" children spent significantly more time on a spelling task when using a speech synthesizer. However, while such an explanation may account for the superior performance of the speech synthesizer over working independently, it does not account for the difference between the *speech synthesis* and *read aloud* conditions, as both "decoded" for the subjects.

Another possibility is that the *speech synthesis* condition provided a more compelling medium because it was more novel than either the *read aloud* or *no assistance* conditions. A higher degree of interest in the proofreading activity under the *speech synthesis* condition may have resulted in a higher level of "engagement" or "attention to task." The greater degree of engagement may have also increased the number of times subjects reviewed the text and enhanced error detection. Riefer (1987) found that the number of readings positively correlated with the number of errors detected. In contrast, the improved performance under the *speech synthesis* condition may have had less to do with the speech/auditory feedback itself than with other factors related to that condition. For example, the *speech synthesis* condition was the only condition in which a computer was used. Perhaps the computer, in and of itself, resulted in a greater degree of engagement. Collins (1990) found that the use of a word processor significantly improved the attitude of college students with learning disabilities toward writing.

Perhaps the visual highlighting of individual words (without speech) by the block cursor was the critical factor in improved performance under the *speech synthesis* condition. The possible benefits of highlighting/isolating individual words for children with reading disabilities have been discussed by others (Jarvella & Lundberg, 1989; Lundberg & Leong, 1986). It is interesting to note that capitalization was one of two categories in which the *speech synthesis* condition outperformed the other two conditions at a statistically significant level and that the synthesizer did not voice whether letters were capitalized or not. In this instance, was it the highlighting rather that the speech that was the pivotal factor? However, this notion needs to be tempered with the understanding that while the synthesizer did not voice capitalization, it may have alerted subjects to punctuation omissions (via prosody, e.g., anticipated pauses or changes in intonation) at the end of sentences, and in turn, to the lack of capitals on subsequent words. This interpretation is speculative and will require additional research.

It is also possible that neither the speech nor highlighting in isolation were responsible for enhanced performance under the *speech synthesis* condition, but rather the simultaneous interaction of both. The benefits of simultaneous auditory and visual input is described in the literature on "neuro-impress" approaches to reading (see Smith, 1991, p.444). Such a determination is not discernable from the present data, but suggests an interesting avenue for future research.

Although the *speech synthesis* condition outperformed the other two conditions overall, it must be kept in mind that there were two error categories in which the other proofreading conditions surpassed the use of the speech synthesis/screen review system. More grammar-mechanical errors were found by the subjects when the text was read to them by a human reader. This difference was statistically significant. Additionally, errors of content/organization were found more readily under the *no assistance* condition than under the other two conditions (SS, RA). However these differences were not statistically significant.

The reason that the *read aloud* condition fared better than the *speech synthesis* condition with regard to grammar-mechanical errors is not easily determined. It is possible, however, that the human reader provided more paralinguistic information related to syntax (e.g., changes in stress, intonation, volume, pauses) in this error category which involves syntax more directly than the others, thereby cuing the subject to a greater number of errors. Although the reader made an attempt to refrain from cuing subjects at specific "error points," any native speaker is nevertheless "bound" by syntactic rules, which to some extent, mandate paralinguistic processes which would not have been provided by the speech synthesizer. Research on silent pauses, filled pauses ("uh," "ya' know," "like") and breathing suggest that these occur at specific syntactic junctures within and between sentence boundaries (Boomer, 1965; Goldman-Eisler, 1968; Martin, 1971; Ross & Cooper, 1979). These pauses have been observed in generating both dictated and handwritten discourse (Matsuhashi, 1987). For example, consider the following sentences:

Human Reader: *Some students smirk [human pauses] while another gave his speech.*

Speech Synthesizer: *Some students smirk while another gave his speech.*

The synthesizer reads the sentence "flatly" without the stress or pause at the juncture between the independent and dependent clause. In contrast, a human reader is almost compelled to pause, if only briefly, between the clauses, thereby alerting the subject, possibly, to the verb tense error (*smirk/gave*).

It could then be argued that the grammar-global category also "syntactically bound" the human reader to giving cues to errors. However, the grammar-global category consisted of only two types of errors-- run-on sentences and sentence fragments. Perhaps the human reader was able to guard against these more obvious syntax flaws in time to inhibit cuing, thus explaining why the human reader did not perform better than speech synthesis in this category. In any case, the differences between the conditions were not pronounced enough to be statistically significant for the grammar-global category.

As noted, the *no assistance* condition outperformed (although not at a statistically significant level) the other two conditions on errors of content/organization. By definition, this category included errors involving "gross semantic confusions, underlying content repetition, incoherent phrases, required paragraphs (as in direct quotation), misplaced sentences, etc.." As errors within this category are not directly tied to linguistic elements (e.g., syntax, morphology, phonology, semantics) they might be viewed as "extra-linguistic" and perhaps not as accessible to the subject through the speech/oral language provided by the synthesizer or human reader. Again, interpretation of these findings need to be made with extreme caution, since differences were not statistically significant. Furthermore, the total number of errors of content/organization (10 for all conditions) was the lowest number found for any category. Interpretation of this finding is also complicated by the fact that subjects were free to choose any strategy they preferred. So while the overall condition was classified as "no assistance," the subject may have employed a wide variety of proofreading strategies (reading aloud, reading backwards).

Implications

The fact that the *speech synthesis* condition outperformed the other two conditions overall and in several categories, suggests that the use of a speech synthesis system offers a viable alternative to both a human reader and working alone as a means by which postsecondary students with learning disabilities can locate their written language errors. However, this finding once again needs to be tempered by acknowledging that while statistically significant, there was only a 3.5% difference in overall error detection rate between the *speech synthesis* and *read aloud* conditions. Consequently, one should be cautious in interpreting these results as a "wholesale" endorsement of speech synthesis over the use of a human reader. At the same time, it should be kept in mind that while the differences between the *speech synthesis* and *read aloud* condition were small, they were achieved with "minimal effort"-- the simple provision of the speech synthesis system and only fifteen to twenty minutes of training.

Although the *speech synthesis* condition proved to be the most effective proofreading method overall, the number of errors found under this condition could nonetheless be considered relatively small. The total number of errors made for all subjects (on the combined third for the SS condition) was 1,123. Out of this number, only 399 or 35.5% were found using the speech synthesizer. Consequently, an argument could be made against the overall effectiveness of the speech synthesis system since the majority of errors were still not found (64.5%). On the other hand, it should be stressed that even one "small error," such as the omission of one word (e.g., "They were present" vs. "They were <u>not</u> present"), could result in a totally different communication, which in turn could mean the difference between passing or failing an examination.

The knowledge that speech synthesis is a viable alternative in assisting postsecondary students with learning disabilities to proofread their written documents is extremely important considering the shortage of personnel and rising costs associated with providing support services to the ever increasing number of students with learning disabilities entering postsecondary institutions. The use of a speech synthesis system may provide an effective means by which postsecondary learning disability service programs can substitute or supplement support service personnel (i.e., human readers), the availability of whom can be difficult to secure (Vogel, 1987). Furthermore, it is possible that the use of a speech synthesis system may be more cost effective than providing human readers. The cost associated with training, scheduling and paying readers, is likely to exceed the cost of purchasing speech synthesis systems and training students with learning disabilities in the use of this assistive technology. For example, preliminary cost analysis data from the CSUN Learning Disability Program has indicated that the use of speech synthesis, as opposed to human readers, may reduce costs by as much as 54% for exams in which requests are made for proctors to read written responses aloud. A detailed cost analysis is now being conducted as part of the overall project to precisely determine the cost effectiveness of employing speech synthesis, and will be reported in subsequent writings.

It is also important to consider that in addition to its potential cost effectiveness, a speech synthesis system (as opposed to a human reader) may assist postsecondary students with learning disabilities in their struggle for independence. A speech synthesis system is controlled by the student and does not require the presence of another person. Reducing reliance on others may serve to empower and "liberate" students with learning disabilities.

The finding that the speech synthesis/screen review system did not fare better than the other two conditions with regard to all of the nine error categories suggests that this technology should not be employed as a technique to enhance proofreading for all types of errors. A preferable strategy might be to encourage students with learning disabilities to select from a repertoire of proofreading strategies (when the situation permits), with each one matched to the search for specific kinds of errors. For example, a human reader might be the preferred condition for identifying grammar-mechanical errors, while using a speech synthesizer might be the most beneficial for detecting errors of capitalization or usage.

Proofreading strategies, other than those studied in this experiment, might also provide a viable option for finding specific kinds of errors. This might include commonly employed techniques like reading backwards or reading aloud, as well as proofreading (grammar checkers) software programs. It should be noted, however, that the effectiveness of such techniques has not been substantiated (DeNight, 1992; Frankel, 1990; Riefer, 1987). Any recommendation as to the specific proofreading method will also need to be considered relative to the specific disability, the developmental level of the student, the particular genre of writing (e.g., narration, explanation) and the particular contexts.

Limitations

This research must be viewed in light of several limitations. First of all, the sample size was small (N = 33) and may therefore, not be representative of the postsecondary learning disability population as a whole. Additionally, the majority of these subjects were "white" and "middle-class." A more diverse sample may have yielded different results, especially with those students who are not native English speakers or who are predominantly speakers of Black English Vernacular. Furthermore, although subjects in the sample were identified as having a "learning disability in the area of written language," the precise written language difficulties (e.g., grammar, spelling, organization) were not identified, putting the homogeneity of the sample in question.

This study was also limited in that only one speech synthesis system was utilized. Perhaps other speech synthesis systems would have produced divergent findings. Similarly, the speech synthesis system was compared to only two other strategies, one (NA) which may have involved a number of diverse strategies. Consequently, future research may want to compare speech synthesis with strategies other than those investigated here (e.g., metacognitive). It should also be emphasized that this research was directed toward proofreading (or error detection) and not revision *per se*. According to MacArthur, Graham and Schwartz (1991), identifying the problem is only the first step in the revision process. Consequently, there is no guarantee that finding an error will result in a change that will improve the quality of the text, since the writer still needs to know how to change it, and then be able to make the actual change.

In summary, the use of a speech synthesis/screen review system enabled postsecondary students with learning disabilities to find a greater number of errors in self-generated written language samples as compared to having the text read aloud to them by a reader and to receiving no assistance. Although it did not outperform other methods for all category of errors, it did so in regard to overall errors, as well as in seven out of nine specific categories-- four at a statistically significant level. Future research will need to clarify the precise reasons for its overall effectiveness as well as its effectiveness relative to specific types of errors. Subsequent research would also do well to investigate the utility of speech synthesis relative to specific written language disorders/diagnostic profiles, particular types of writing (e.g., narration, explanation), specific functional contexts, as well as specific speech synthesis systems and proofreading strategies. As was suggested earlier, the novelty of the technology may have resulted in subjects being more "engaged" in the proofreading task. It will be interesting to see if the benefits of the speech synthesis system will be sustained over time as the novelty of the technology wanes.

Perhaps more important than the finding that speech synthesis is a viable proofreading method, is the more general finding that assistive technology offers a viable method of helping persons with learning disabilities compensate for their difficulties. It is hoped that this research will provide the impetus for future investigations regarding the efficacy of assistive technology in enhancing the quality of life for persons with learning disabilities.

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FOOTNOTES

[1] A detailed analysis of the cost effectiveness of speech synthesis is now underway as part of the overall project.

[2] The reason the researcher asked this of participants was simply to ensure that a series of multiple drafts would not be generated for some participants (those who chose to rewrite several versions) and not others. This may have resulted in samples of 3-5 pages for some students, while others may have generated 10, 15 or even more pages in multiple drafts. Also, these "multiple drafters" would then have had to return for subsequent sessions to proofread the new drafts. (Would a practice effect then become an issue?) Another question would be raised as to how these later drafts were assigned to be proofread as to condition. For these and other methodological considerations, the researchers chose to discourage the rewriting of entire sentences and/or paragraphs.

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Table 1

Percent of Errors Found by Condition

SS	RA	NA
35.5%	32.0%	25.0%

Table 2

Differences Between Conditions on Percent of Total Errors Found

Condition	Z-score	Probability
SS-RA	1.74	.04
SS-NA	5.48	.00005
RA-NA	3.70	.0001

Table 3

<u>Percentages of Errors Found by Condition and Category</u>

Category	Condition		
	SS	RA	NA
Capitalization	33**	18	19
Punctuation	18	16	15
Spelling	48*	45*	33
Usage	33**	6	17*
Grammar-Mechanical	22	35**	20
Grammar-Global	29	26	24
Typographical	61*	52	40
Content/Organization	11	10	13
Style	33	21	18

* Significant when compared to one other condition

** Significant when compared to both other conditions

Table 4

Significance Levels Between Conditions on

Percent of Errors Found by Category

	Paired Conditions		
Category	SS-RA	SS-NA	RA-NA
Capitalization	.0005	.0009	---
Punctuation	---	---	---
Spelling	---	.00005	.00006
Usage	.0002	.04	.04
Grammar-Mechanical	.004	---	.0009
Grammar-Global	---	---	---
Typographical	---	.04	---
Content/Organization	---	---	---
Style	---	---	---

Table 5

Number and Percentage of Errors Made and Found by Category

Category	Total # of Errors Made	% of Total Errors Made	Total # of Errors Found	% of Total Errors Found
Capitalization	595	17.5	144	13.8
Punctuation	374	11.0	60	5.7
Spelling	1,357	39.9	567	54.1
Usage	145	4.3	27	2.6
Grammar-Mech	485	14.2	124	11.8
Grammar-Global	173	5.1	45	4.3
Typographical	99	2.9	51	4.9
Content/Organ	90	2.6	10	1.0
Style	85	2.5	19	1.8
TOTALS	3,403	100.0	1,047	100.0

Compensatory Effectiveness of Speech Recognition on the Written Composition Performance of Postsecondary Students with Learning Disabilities[1]

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Running head: SPEECH RECOGNITION AND WRITING

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Abstract. Seventeen males and twelve females wrote essays under three conditions: (a) without assistance; (b) using a human transcriber; and (c) using a speech recognition system. Students received higher holistic scores using speech recognition than when writing without assistance at a statistically significant level ($P=.048$).

In order to determine the reasons for the superior scores on the essays written using speech recognition, 22 measures of fluency, vocabulary and syntax were computed. Several measures showed a strong correlation with the holistic score. A multiple regression revealed the best predictor of the holistic score was Words with Seven or More Letters. Further, the ratio of Words with Seven or More Letters to Words differed significantly across conditions ($P=.0136$) in favor of speech recognition when compared with receiving no assistance.

A factor analysis identified three factors that accounted for significant variation in holistic score: Factor 1, measures related to length of the essay ($P=.0001+$); Factor 2, measures of morphological complexity ($P=.003$); and Factor 3, main verbs ($P=.021$). The authors suggest that the technology may have been successful because it "encouraged" the use of longer words, a powerful predictor of a holistic score.

A person with a learning disability often experiences great apprehension when making the decision to attend college. Will longer hours of study and extra effort alone be enough to compensate for the deficits associated with his or her disability?

One of the most demanding challenges faced by a person with a learning disability who chooses to attend a postsecondary institution is the area of written composition. More than 90% of adults with learning disabilites report significant problems with writing and/or spelling (Blalock, 1981; Cordoni, 1979; Vogel & Moran, 1982). Recognition of these difficulties by postsecondary disabled student service programs, coupled with federal legislation (Section 504 of the Rehabilitation Act of 1973) mandating "academic adjustments" for students with disabilities (including learning disabilities) has prompted the development of a number of compensatory writing strategies (Mangrum & Strichart, 1984). One such strategy is the use of a human transcriber-- a person who writes down what a student dictates when taking exams or preparing class assignments. The notion that dictating to a transcriber might help compensate for writing difficulties is perhaps the result of research in the field of both language development and learning disabilities that has long contended that students' oral language performance precedes and exceeds their written performance (Howell, 1956; King & Rentel, 1981; Myklebust, 1973; Wilson, 1963).

Recent developments in the area of speech recognition technology (i.e., reduced cost, accuracy, ease of use) has led to a possible alternative to the "traditional" dictation strategy used by many postsecondary support service programs. Speech recognition systems operate in conjunction with word processing programs to allow the user to produce written text through speech. The user dictates (word by word) into a headphone-mounted microphone, and the system (hardware and software) converts the spoken words to electronic text on a computer monitor.

This technological writing strategy is intended to enable postsecondary students with learning disabilities to circumvent writing difficulties by tapping into (presumed) oral language and oral vocabulary strengths, while at the same time escaping some of the shortcomings of using human transcribers, including burgeoning costs for obtaining services, time and availability considerations, and loss of independence (Raskind, 1994). Despite encouraging clinical reports by professionals (Brown, 1987; Raskind & Scott, 1993) and enthusiastic testimonials by users, little controlled research has evaluated the effectiveness of speech recognition in helping postsecondary students with learning disabilities compensate for written language difficulties. In 1991, the Office of Disabled Student Services at California State University, Northridge, obtained a grant through the United States Department of Education (Fund for the Improvement of Postsecondary Education) to investigate three promising technologies to assist students with learning disabilities in overcoming their academic difficulties. One of these technologies was speech recognition.

In an effort to address the lack of research and to determine the effectiveness of speech recognition compared to writing without assistance and the more traditional strategy of using human transcribers, each student in the study was asked to compose three essays, one under each of the following conditions: (a) using speech recognition technology (SR); (b) writing without assistance (NA); and (c) using a human transcriber (TR). The writing task was designed to emulate the Upper Division Written Proficiency Exam that all California State University, Northridge students must pass in order to graduate. It is a holistically scored examination in which students compose an essay on an assigned topic within a fixed period of time.

It was predicted that essays written using speech recognition would receive higher holistic scores than those written under the transcribed condition, <u>and</u> that both of these would show higher holistic scores than essays written without assistance. First, as noted, although positive results using human transcribers have been described throughout the literature, recent researchers have found that certain weaknesses remain uncorrected in the writing of students both with and without learning disabilities (Gould, 1980; MacArthur & Graham, 1987; Scardamalia, Bereiter, & Goelman, 1982). Further, in a related study on proofreading (Raskind & Higgins, this issue) students located and corrected more errors using technology (speech synthesis/screen review) than when a human reader was used or when proofreading without assistance. Finally, the authors hypothesized that some of the special features of speech recognition technology (e.g., capacity to generate correctly spelled text and enhanced ability to edit large segments of text after dictation) might give the technology an edge over human transcriber in generating a superior finished product. Specifically, the following three hypotheses were tested: (a) The number of students who receive higher holistic scores using speech recognition than when writing without assistance will exceed the number of students who receive higher scores on the "no assistance" essay; (b) the number of students receiving higher holistic scores using a human transcriber than when writing without assistance will exceed the number of students receiving higher scores on the "no assistance" essay; and (c) the number of students who receive higher scores using speech recognition than under the transcribed condition will exceed the number of students receiving higher scores on the "transcribed" essays.

METHOD

Subjects

Twenty-nine postsecondary students enrolled at California State University, Northridge (hereinafter CSUN), participated in the written composition/speech recognition portion of the study. CSUN is a state university offering a full undergraduate program as well as a graduate division that grants master's degrees in several disciplines. The population of students reflects the larger community in which the university is embedded: Northridge is a predominantly middle-class, multi-ethnic suburb of Los Angeles located in the San Fernando Valley. On a scale of 1-5 (lowest to highest) self-ratings on socioeconmic status were: 1=1, 2=3, 3=16, 4=9 and 5=0. Three students identified themselves as African-Americans, 23 as Caucasian, three as Hispanic and none as Asian. Fifteen percent were freshmen, 17% sophomores, 29% juniors, 27% seniors, and 12% graduate students. Their average age was 24.9. Mean IQ was 97, and mean written language score was 83.5. All subjects had been identified previously as having a learning disability under the criteria specified by the Chancellor's Office of the California State University (CSU) system. These criteria include (a) significant intracognitive discrepancy(ies), and/or (b) significant aptitude/achievement discrepancy(ies), and (c) at least one standard score in the average range of aptitude (greater than or equal to 90), and (d) an average or greater score (25th percentile or above) in at least one academic area. CSU criteria are used in conjunction with a systemwide definition of learning disabilities adapted from the National Joint Committee on Learning Disabilities (Hammill, Leigh, McNutt, & Larsen, 1981). In addition, all participants showed a discrepancy of 12 or more standard score points between language achievement as measured by the *Woodcock-Johnson Psycho-Educational Battery, Part II* and written language aptitude as measured by the *Woodcock-Johnson Psycho-Educational Battery, Part I* (Woodcock & Johnson, 1977), or written language achievement and IQ as measured by the *Wechsler Adult Intelligence Scale-Revised* (Wechsler, 1981). In a few cases where assessment had been conducted at other institutions, alternative standardized tests of written language performance and aptitude were substituted to determine the specific disability in written language.

Equipment

The equipment consisted of an IBM-compatible, 486 computer with eight megabytes of random access memory, upon which a "DragonDictate®" system, Version 1.01, was installed. The system operated in conjunction with WordPerfect 5.0 software. The system used develops a phonetic model of each student's voice, which is paired with entries from its 30,000-word English vocabulary file. The phonetic model of a word improves over time so that the system makes better and better "guesses" with each utterance of it. All keyboard and editing commands can be controlled by either speech or manual interaction with the keyboard.

Procedure

The University's Upper Division Written Proficiency Exam, which students must pass in order to graduate, was chosen as the primary assessment tool. This timed essay test is holistically scored on a scale of 1-6, with a grade of 4 or above required for passage. The universitywide success rate is approximately 75%. Participants in the study were given instructions identical to those on the actual exam and old test questions were employed to ensure comparability of the task. One of six possible questions was randomly assigned to each administration of an exam. The only accommodation made for students in the study was to grant them extra time if needed (up to one hour). This is the normal procedure practiced by the university to accommodate students with learning disabilities. The instructions (attached as Appendix A), and the test question, were read aloud by one of the researchers as each student followed along.

Participants wrote three essays, one for each of the following conditions: (a) using a speech recognition system (SR); (b) dictating the essay to a human transcriber (TR); and (c) without assistance (NA). Students were allowed to handwrite or use a word processing program to generate the "no assistance" essay, but were not allowed to use the spell checking function. All transcriptions were done by a single transcriber, one of the researchers. Handwritten and transcribed essays were typed verbatim, converted to word processing documents, and proofread for accuracy to the original.

Since the training on the speech recognition program involved between five and ten hours, the researchers suspected that a training effect might occur. To assess such an effect, students were placed in one of two experimental groups. Group A received training on the speech recognition program first and then took all three essay exams (i.e., one with speech recognition, one using a transcriber, and one with no assistance). Students in Group B first took two of the exams under the "no assistance" and "transcribed" conditions (also randomly assigned), then received training, and took the final exam using the speech recognition equipment. Since a practice effect, as well as a training effect was possible, the order in which the exams were administered was randomly assigned, and the size of Group A and B was counterbalanced so that no condition received an advantage due to position.

Use of Equipment and Training Procedures

Speech recognition systems were originally used in the Computer Access Lab at

CSUN as assistive technology for other disabled populations such as persons with profound motor impairment and/or communicative disorders. These populations use speech exclusively to activate all commands and vocabulary corrections required for operation. Based on experience with these other populations, the researchers estimated that up to 20 hours of training would be required of students with learning disabilities to become facile at operating the system. During the process of their own training, however, the researchers discovered that persons without severe motor impairment could comfortably switch from using voice commands to using the keyboard to execute many routine operations. This was especially helpful in correcting errors the system made in "guessing" the word just spoken. The procedure for correcting such an error using voice commands exclusively involves spelling out the word orally, using the International Communications Alphabet (alpha, bravo, etc.). This was a highly tedious and distracting procedure for the researchers and was expected to be even more so for a person with a learning disability. Fortunately, the alternative of simply striking the first letter of the desired word on the keyboard frequently resulted in the correct choice being generated, which greatly shortened training time.

A training program was developed wherein the trainer spent one hour introducing the student to basic operations and training a small set of 100 commands. During the second hour of training, the student was trained on how to correct inaccurate guesses made by the program. Both the "alpha-bravo" method and the keyboard method were taught, and students were given the choice of using either procedure from that point on. (All but one student consistently chose the keyboard method of correction, and even he soon abandoned the voice-only procedure.)

During their own training the researchers found that they felt comfortable enough to use the equipment for actual composition purposes when the system reached an accuracy level of six out of seven correct words guessed. The students, however, expressed a level of comfort at a much lower accuracy rate, closer to one error for every four or five words. This cut training time even more, resulting in an average training time across the study of 5.8 hours.

After the first two hours described above, the standard procedure for a training session was for the researcher to sit next to the student as he or she dictated self-generated sentences into the equipment. This was necessary during the training phase to monitor many students' tendency to pass over wrong word choices made by the system. If such errors were allowed to remain in computer memory, the students' files would eventually become so corrupted that the system would cease to be useful.

The students were deemed finished with the training period when they: (a) spontaneously corrected errors at a 90% level without prompting from the researcher; and (b) expressed to the researcher that a comfortable level of accuracy had been reached so that a composition could be generated without interference with normal thought processes.

Scoring

All compositions were scored by two readers with previous experience reading for actual Upper Division Written Proficiency Exams. The raters were instructed to give the essays a single, holistic score using the criteria used in actual Upper Division Written Proficiency Exams. (The Scoring Guide given all readers for those exams is attached as Appendix B.) In the cases of discrepancy in scores, a third reader independently scored the composition. This is the standard procedure used by the university in scoring an examination. All readers were blind to the condition under which the essays had been administered. Interrater reliability between all readers (the two readers and the tie-breaking third reader) was .93.[2]

RESULTS

As to potential confounding variables, no significant differences in holistic scores were found due to training effect between Group B (those who first received training, then took all three exams) and Group A (those who took the "no assistance" and "transcribed" conditions before training, received training on the technology, then took the third exam using the technology). Similarly, no differences were found in holistic scores due to the particular question answered or to the order of the conditions (practice effect).

Holistic Scores

A simple tally of wins and losses revealed that when comparing the speech recognition compositions with those generated without assistance, 13 students scored higher using the technology, while only 5 received a higher score without assistance, which was significant at the .048 level (see Table 1).

[Insert Table 1]

When comparing transcribed essays with the "no assistance" condition, 11 scored higher on the transcribed and 6 on the "no assistance" essays. This did not reach significance. A comparison of speech recognition with transcribed essays showed that the technology condition received a higher score eight times and transcriptions six, which was not significant.

[2]The two readers each read a total of 81 essays, 27 students x 3 essays = 81. One essay was disqualified. (judged not to have answered the question) leaving 80 essays. Of those, three received different scores between readers. The tie breaker read those three essays, agreeing with one of the readers, and disagreeing with the other for a total of 83 essays and 6 disagreements. Total essays minus disagreements was divided by total essays (83-6/83) for an interrater reliability of .93.

Comparison with Nondisabled Sample

Of interest to both the researchers and the university was the question of how students with learning disabilities fared in comparison to their nondisabled peers. Since it was known in advance that the scores on actual administrations of the Upper Division Written Proficiency Exam were not normally distributed, (i.e., 75% of the scores were 4 and above), the researchers used the real distribution of a single administration of the exam taken by (presumably) nondisabled students to obtain expected frequencies of scores for the comparison. The administration counted contained over 2,300 scores and over 1,000 compositions. The proportions of scores on the actual administration were computed for the number of essay scores for the 26 subjects in the study (at least two readers read each essay, and in some cases three if the tie-breaking reader read the essay also). There were 53 scores for "no assistance" essays, 53 for "transcribed" essays and 55 for "speech recognition" essays. Therefore, the "expected frequency" column in Table 2, represents the proportion of each holistic score that would be expected, given N = 53, N = 53, and N = 55 scores. A Chi-square test of expected distribution was then conducted (Frude, 1987; Norusis, 1990). Due to a low frequency of scores of 1 or 2 in the real exam and the small sample size in the study, these two ranks were collapsed with scores of 3. Similarly, rank 5 and 6 also had to be collapsed to meet the assumptions of the Chi-square test. Results of the test are shown in Table 2.

[Table 2]

As is true of students with learning disabilities in general (Gajar, 1989; Gregg, 1983; Vogel & Moran, 1982), the scores for the population of students participating in the study differed significantly from the expected frequencies taken from the nondisabled population, evidencing their poorer performance. Both the "no assistance" condition and the "transcribed" condition continued to show significant differences in frequencies from the nondisabled sample. However, the frequencies of scores on compositions generated using speech recognition more closely resembled the distribution from the nondisabled population and, in fact, did not differ significantly from that group. The pass/fail rate for the "speech recognition" condition on the mock exams also showed no significant difference from the distribution of the nondisabled students taken from the real administration of an exam. This is especially heartening, since actual Upper Division Written Proficiency Exams are taken by juniors, seniors, and graduate students only, while the population in the study contained freshmen and sophomores as well.

Although differences between the transcribed and speech recognition conditions were not great, these further positive findings reinforce the conclusion that speech recognition was effective in improving holistic scores.

POST-HOC EXPLORATORY ANALYSIS

In an effort to determine whether the technology may have influenced other measures of written language, and to shed further light on the mechanisms by which the technology may have influenced the main variable, holistic score, compositions were analyzed on various measures used by other researchers to assess written language (See Newcomer & Barenbaum, 1991, for a review of recent literature).

Measures of **fluency** included number of words, sentences, morphemes, t-units, propositions (Barenbaum, Newcomer, & Nodine, 1987; Crowder, 1982; Gajar, 1989; Gajar & Harriman, 1987; Houck & Billingsley, 1989; Kintsch & Keenan, 1973; Klima & Bellugi, 1979; Moran, 1981a; Myklebust, 1973; Nodine, Barenbaum, & Newcomer, 1985; Poteet, 1978; Thomas, Englert, & Gregg, 1987), and main verbs. Measures of **vocabulary** included number of unique words, words of seven or more letters, number of adjectives, and number of adverbs (Barenbaum et al.. 1987; Deno, Marston, & Mirkin, 1982; Gajar, 1989; Houck & Billingsley, 1989). The following measures of **syntactic complexity** were also calculated: number of morphemes per t-unit, ratio of complex t-units to t-units (Moran, 1981b), words per proposition, propositions per sentence, words per sentence and main verbs per sentence. Ratios of adjectives, adverbs, words with seven or more letters and unique words to words in the document were also calculated. Gajar (1989) suggested using Carroll's type/token ratio (Carroll, 1964), unique words divided by words, times the constant 1/sq.rt of 2, which she purports corrects for the length of the essay. Lastly, 30 of the exams, 10 from each condition, were proofread for errors by two outside readers using a nine-category classification system developed by Raskind and Higgins (this issue). Errors were classified as: capitalization, punctuation. spelling, usage, grammar/mechanical, grammar/global, typographical, content/organizational or literary/stylistic. Interrater reliability was .90 for total errors found and .94 for category placement. Interrater reliability for each category was as follows: capitalization. 1.00; punctuation, .96; spelling, .99; usage, .90; grammar/mechanical, .93; grammar/global, .90; typographical, .97; content/organization, .90; and literary style, .86.[3]

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[3]Each rater was paired with the researcher and the other rater for a total of three pairs (A-B. A-C. B-C). Each error marked on an essay by either one of the raters in a pairing was determined to be the "same" if. and only if. the other rater also found that particular error. The total errors marked by either rater minus those that were not the "same" was divided by total errors to obtain a reliability score for that essay and pairing. This resulted in 30 essay scores per pairing. There were three pairings. resulting in 30 x 3 = 90 reliability scores. The average of the 90 scores is reflected in the interrater reliability scores reported above.

Scoring

Words, Sentences[4], Adjectives, Adverbs, and Main Verbs[5] were counted by computer, as were Unique Words and Words of Seven or More Letters[6]. Due to practical and financial considerations, a single scorer (one of the researchers) counted morphemes for all the essays. Thirty of the essays were then scored by two independent readers to establish reliability for morphemes. Interrater reliability for all three scorers was .97.[7] A similar approach was taken with respect to t-units. One author scored all essays and two independent scorers read thirty of the essays to establish interrater reliability, which was .96. The authors could find at least three different descriptions for marking t-units (*cf* Hunt, 1970, "minimal terminable unit", p. 4; Hammill & Larsen, 1978, "thought unit", p. 22; Moran, 1981a, "complex v. compound t-units", p. 8). The *Test of Written Language* protocol was employed (Hammill & Larsen, 1978), which reads. "...a segment of meaningful expression that contains an identifiable verb and its subject, and that can stand alone, i.e., a complete sentence" (p. 22). The counting of propositions is described generally by Crowder (1982), Klima and Bellugi (1979), Kintsch and Keenan (1973) and more explicitly by Bovair and Kieras (1985).[8]

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[4] An analysis document was duplicated from the original. and all periods were removed following titles. abbreviations. and initials. The number of sentences was then defined by the number of periods in the document; words were counted by using the word count function of the word processing system (which counts spaces following words).

[5] The grammar check program Gramatik® was modified to count adjectives. adverbs. and main verbs.

[6] Words in the essay were alphabetized by computer and tallies made of Unique Words and Words of Seven or More Letters.

[7] Each rater was paired with the researcher and the other rater for a total of three pairs (A-B. A-C. B-C). Each morpheme marked on an essay by either one of the raters in a pairing was determined to be the "same," if and only if the other rater also marked that particular morpheme. The total morphemes marked by either rater minus those that were not the "same" was divided by total morphemes to obtain a reliability score for that essay and pairing. This resulted in 30 essay scores per pairing. There were three pairings, resulting in 30 x 3 = 90 reliability scores. The average of the 90 scores is reflected in the interrater reliability score reported above.

[8] Propositions, in the most general terms. are the underlying cognitive representations of a sentence. A single sentence can contain more than one proposition. For example. the sentence. "John loves Mary." has one proposition [love. John Mary], while "I think John loves Mary" has two [think. I S [love. John Mary]]. "John loves lovely Mary" would also have two [love. John Mary] and [lovely. Mary].

This being the exploratory part of the study. as an experimental procedure. propositions were checked against the count of Main Verbs

Correlations with Holistic Score

Table 3 lists the Pearson's correlation coefficients of each of the measures with holistic scores. Number of Words with Seven or More Letters showed the highest correlation with the holistic score (.5682, p = .0001+). The second highest correlation was with Number of Morphemes (.5122, p = .0001+), followed closely by Number of Words (.4878, p = .0001+). All but three of the statistically significant correlations disappeared when "corrected" for the influence of length of essay-- Words of Seven or More Letters, which remained positively correlated, and Main Verbs and Unique Words, which became negatively correlated. (A correlation coefficient matrix, which measures the tendency of each of the variables to covary with one another, confirmed that length of essay was correlated with many of the other measures.) This suggests that only these three measures hold up independently (from length of essay) as being correlated strongly with holistic scores.

[Table 3]

Multiple Regression Analysis

A stepwise multiple regression analysis (Einstein & Nocks, 1987) was conducted on the measures individually to test their covariance with the holistic score in order to determine which, if any, of the variables were useful as independent "predictors" of the holistic score. Two variables emerged as significant indicators. Words of Seven or More Letters was the best predictor, explaining 32% of the variation in holistic score. The second best predictor (which was not redundant with information already obtained from Words with Seven or More Letters) was Main Verbs per Sentence, which was negatively correlated. These two

plus Adjectives and Adverbs to see if they would approximate a count of propositions. The total consistently fell within 5% of the number of propositions. Therefore, this total was henceforth used to check the accuracy of proposition counts, saving the researchers countless hours training scorers to a proficiency level sufficient to allow reliable interrater identification of these constructs.

variables together accounted for 39% of the variation in the holistic score. These findings further confirmed that two of the three measures were good independent predictors of the holistic score.

Factor Analysis

Six factors emerged from a factor analysis with oblique rotation run on the 22 measures using the SPSS procedure FACTOR (Norusis, 1991). The measures that loaded heavily on each factor are listed in Table 4 in descending order as to how well the factor accounted for the total variance of that measure.

[Table 4]

Percentage of the total variance in the set of essays for Factors 1-6, respectively, was as follows: 42%, 12%, 11%, 7%, 7%, and 6%.

Stepwise Multiple Regression on Factors

After each of the essays was scored on the six factors, a stepwise multiple regression of the influence of the factors on the holistic score was run as suggested by Hedderson (1991).[9] Factors 1, 2 and 3 emerged as "predicting" a statistically significant amount of the variance in holistic scores $t = 5.668$ ($p=.0001+$), $t = 3.083$ ($p=.003$), $t = -2.090$ ($p=.04$), respectively. The addition of Factors 4, 5 and 6 did not contribute significantly to the model (nor had these factors correlate significantly with holistic score).

[9] The procedure simply applies the SPSS procedure STEPWISE to the data, after each essay has been given a score on each of the factors previously identified using FACTOR. STEPWISE attempts to determine the best multiple regression model for predicting variation in the dependent variable (holistic score), using the previously assigned factor scores. It begins with the factor that best predicts the outcome and adds the six factors in a stepwise progression (providing Beta, t-values, residuals, R^2, etc., which allows the user to decide when factors cease to add significantly to the predictive power of the model). Using the study's data, Factor 1, which contained measures related to fluency or length of essay, was entered as the first step. STEPWISE then chose Factor 2, which contained vocabulary and morpheme-related measures, and continued to add the remaining factors in the order in which they best predicted the holistic score.

DISCUSSION

Findings Concerning the Technology

The major findings of the study clearly indicate that speech recognition assists students with learning disabilities in compensating for their difficulties in written composition. When compared to receiving no assistance, students received higher holistic scores using the technology.

The data provided by the exploratory analysis of the compositions suggest a possible mechanism by which this result might be occurring. First, the stepwise multiple regression for individual measures found that the single most sensitive predictor of the holistic score was Words of Seven or More Letters, "big words." Second, a comparison of the means of a closely related measure (ratio of Words of Seven or More Letter to Words) across the "no assistance" and "speech recognition" conditions showed a significant difference in favor of the technology ($P=.0136$)[10]. Speech recognition apparently allowed students to use their more extensively developed oral vocabularies at a level that was statistically significant.

The researchers have postulated at least two possible explanations for how the technology may have been responsible for the above results. First, the dictated words that appear on the screen are automatically spelled correctly for the student. Throughout the study, many students with spelling difficulties confirmed that a typical writing strategy for them was to substitute a "baby" word for the word they really wanted to use to avoid the embarrassment of spelling it incorrectly. One can imagine that over time, this strategy would have a truncating effect on the written vocabulary of otherwise unimpaired writers.

[10] This value falls within a 95% confidence interval using the Boniferroni method of correcting for experimental error (Norusis, 1993).

Further, freedom from the mental distraction of constantly having to check and recheck spelling was frequently reported by the students in the study as one of the most positive features of the equipment. These comments suggest that the technology allowed the students to attend to the more important concerns of content, organization, and effective use of language.

Secondly, the speech recognition system may actually have been encouraging students' use of longer words. The program was much better at making correct guesses for longer words than for short, uni-syllabic ones. This is because there is more phonetic information to go on with a longer, multisyllabic word and fewer words with which the phonetic model of it can become confused. Over time, students noticed this tendency, and often commented on it. In an effort to get the machine to quit stumbling quite so much, they would select a longer word where a short one might have sufficed.

Contextual and social influences, although difficult to quantify, nonetheless influence performance and, when known, deserve report. Hence, we wish to specify the more obvious and indisputable social/contextual concomitants to use of the equipment and other compensatory strategies in order to alert future users and/or researchers to their existence. For example, although differences did not reach significance, it bears mention that while the dictation strategy did assist students in writing "better" essays, the technology actually outperformed human transcribers as a means of compensating for students' written language difficulties.

Explanation of these findings probably lies outside of the domain of a strictly quantitative study (i.e., in the area of socially acceptable behavior toward helpers of this type). First, it is not "good manners" to keep people waiting a long time. Consequently, students may have spent less time planning and organizing their transcribed essays before beginning to write. Second. students offered many verbal apologies whenever they asked the transcriber to reread portions of the text, which would indicate that they were embarrassed when making such requests. This was especially true if a certain passage needed to be read more than once. (It is one thing to ask someone to read a sentence through for you, but quite another to ask for a fifth or sixth reading of it.) Additionally, some students probably had more difficulty reading the essays written in the cursive form than in computer-generated text on the screen. This overall reluctance to read the essay as it was being generated could restrict students' ability to construct smooth transitional sentences and prevent them from benefitting from associational cues contained in previously written portions.

Another reason the equipment-generated essays may have fared slightly better than handwritten transcriptions is that organizational revisions could be made to the computer documents, which were not possible with the handwritten forms. For students with a "sequencing difficulty" (of sentences, events in time, etc.), this could mean the difference between passage and failure. Intersentence and interparagraph rearrangements are awkward at best in a handwritten document (e.g., arrows, sentence numbering, interpage insertions), not to mention the fact that they are frequently ignored by readers of those essays.

Findings Concerning the Evaluation of Written Language

The data generated by the study offered the researchers a unique opportunity to compare approaches to written language assessment for persons with learning disabilities at the postsecondary level. The writing task evoked language samples much longer than those of previous studies.[11] This allowed for a fuller exploration of the abilities of writers with learning disabilities in the area of development of content, the variation in style at particular points during a composition of considerable length, and strengths and weaknesses of the population of writers with learning disabilities at handling such global tasks as organization of extended pieces, interparagraph transitional devices, elaborative use of detail and supporting evidence, drawing of conclusions, and the like. The holistic scoring of the exams predisposed the researchers to attend to such macro-information, if only to understand why a particular essay succeeded while another failed in an effort to determine the means by which the technology could have contributed to the overall impression of the essay.

On the other hand, the micro-analysis also yielded extremely valuable insights into the characteristics of writers with learning disabilities in relation to the standards to which they are being expected to perform. For example, the sheer length of the composition emerged as an extremely powerful variable (despite the admonition in the instructions, "...how well you write is much more important than how much you write..."), while mechanical errors turned out to have very little relationship to holistic score. Such findings have strong implications for what a useful written language curriculum might be for this population of students. For example, an instructional or remedial program that encourages fluency and vocabulary expansion and limits the focus placed on mechanical difficulties appears to be indicated by the findings.

A careful examination of the micro-data uncovered a myriad of other suggestive

[11] Gajar (1989), Gajar & Harriman (1987), Moran (1981a), and Vogel and Moran (1982) all used 30-minute essays for analysis. Only Vogel and Moran reported a mean for total words of 238.88, but one would expect the earlier studies to be of similar length. The mean in the current study was 447.72.

results. For example:

1. The ratio of Unique Words/Words, a variable imputed to measure "mature" (good?) writing (Carroll, 1964; Gajar, 1989; Morris & Crump, 1982), was negatively correlated with composition length, a powerful predictor of holistic score. Upon reflection, it stands to reason that the longer one writes about the same topic, the more likely one is to use the same vocabulary over and over. The previous researchers, working with smaller written samples, would not have had the opportunity to observe this phenomenon. The finding may provide a clue to why different researchers sometimes find contradictory results (working with different age groups and/or utilizing different task variables), as Newcomer and Barrenbaum (1991) pointed out. It is hoped that the exploratory approach taken here, which has paid greater attention to such macro-units as overall composition organization and forms of argument and rhetoric, can be useful in interpreting and integrating micro-measurable data into a model for evaluating written language.

2. The stepwise multiple regression for individual measures revealed that the variable of Words with Seven or More Letters was the single best predictor of the holistic score. The factor analysis showed that it loaded heavily on Factor 1, which contained many variables associated with the length of the essay, and Factor 2, which contained many variables associated with vocabulary and morphological measures. The fact that this variable would respond both to the ability of a writer to write longer essays and his or her ability to manipulate the morphology of the language is a highly plausible explanation for the power of this variable to predict holistic score. Thus, this finding would indicate that more emphasis in the instructional curriculum on

morphological analysis and vocabulary development might reap substantial benefits for persons with learning disabilities.

3. Factors 3 and 4, in which are found several variables related to longer linguistic units such as phrase and sentence syntax and embeddedness, turned out to be less important than word-level or morphologically related measures. Perhaps due to the rush to fully embrace the new theories in the linguistics of the sixties and seventies, à la Chomsky and transformational syntax, this area of language elaboration and development at the morphological level has been too long ignored. Newcomer and Barenbaum (1991) pointed to conflicting evidence regarding the usefulness of such measures as t-units, complex t-units, and morphemes/t-units, which have arisen out of the above influence of transformational grammar and its emphasis on syntactic complexity. Newcomer and Barenbaum contended that research indicates such units do not consistently discriminate learning disabled from nondisabled populations of writers, nor are they reliable indicators of the "maturity" of the writer since there is also conflicting evidence as to whether or not the measures change across grade levels.

LIMITATIONS/FUTURE RESEARCH

The first limitation that should be mentioned is that since the research was conducted on postsecondary students with learning disabilities; the results may not apply to populations of students with learning disabilities at lower grade levels. Specifically, the degree of independence from personal assistance (in both training on and utilization of the equipment) that was achieved by this adult group may not be possible or even desirable for secondary or elementary-aged students. The one-on-one monitoring by trained personnel that would be required for younger students to achieve a comfortable level of operating the system might be so costly that it severely limits the situations in which the technology could be successfully used. It is hoped that future controlled research on speech recognition technology will embrace a variety of age and ability levels so that we can gain a clearer picture of the benefits and drawbacks of committing financial and human resources to use of the technology.

Secondly, the findings of this study were based on a small sample of students (N=29), taken from a population which itself may not be representative of other college-level groups. For example, the authors suspect that IQ and written language achievement scores might be lower than those expected in university settings (*cf.* Vogel, 1985). Additionally, the age range was great (19-43 years old) and the mean age was older than one might expect for some other college populations (24.9). (The state university system in California attracts a high percentage of returning and full-time employed students.) Also, the diversity of the sample population was not great in terms of ethnicity or linguistic/dialectical variation. These are important considerations when working with speech recognition technology, because the phonetic model to which the speaker is matching his or her vocabulary is in standard GLAD (Great Lakes Area Dialect) (Davis, 1949), apparently spoken by a male in his late twenties. Females, older students, and students with strong regional dialects (in the present study, Southern California "Valley Girl" Dialect) (Reed, 1958, 1971; Zappa, 1982) required longer training times (e.g., training time for females was 1.2 hours longer than for males).

Further, any population of students with learning disabilities is going to be composed of a diverse set of specific disabilities in written language, and the current study's participants are no exception. The written language-related problems reported for this population included spelling, organization, fluency, auditory memory, and reading difficulties. In years two and three of the study, the authors plan to explore the possibility that particular cognitive and achievement deficits are more effectively served by the technology than others. If so, this would allow for specific prescription of technological devices based on assessment information alone.

Another limitation to generalizations of the findings of the current study arises out of the possibility of great variation across regions and individual campuses in terms of how written language achievement is assessed. The primary measure of "success" in the current study was "holistic" score. What is meant by this term can vary considerably. For example, the "holistic" score described by Gajar and Harriman (1987) was based on a point system where "scales" of mechanical errors, usage, organization, vocabulary, and so on, were totalled. The procedure used in the present study to arrive at a holistic score, on the other hand, was for independent readers to assess the "overall impression" of the essay, without regard to any particular aspect of expressive skill such as mechanical errors. Notwithstanding such differences in scoring protocols, one would expect departmental and regional biases to play at least some role in how the essays are judged. It may well be that such differences, as well as procedural differences for arriving at consensus among scorers, could vastly affect the criteria for assessing written work and, in turn, the efficacy of using the technology in any particular setting.

The present study investigated the compensatory effectiveness of the technology. Therefore, the results should be used with caution as they apply to instructional/remedial purposes. Thus, although the authors suspect there has been some remedial effect on participants, especially in the areas of written language vocabulary expansion and spelling (as a result of exposure to consistently correct graphemic representations), no evidence of these effects is offered by the present findings.

The research was based on experience with a single speech recognition system. Since the inception of the study, other manufacturers have placed comparable systems on the market. purporting to require less training time, to demonstrate better "interface" with software, and so on. Such claims by manufacturers, although understandably laudatory, may not prove to be substantiated by controlled research. Thus, later versions of the system tested, as well as competing brands, may show quite different findings, even within the same population of subjects. Should present trends hold, one can also expect that the initial cost of such systems will go down, making them more feasible as alternatives in a wider variety of settings. As evidence accumulates concerning such new applications, a more accurate assessment of the effectiveness of the technology may emerge as a more reliable index of its overall usefulness.

Lastly, although the fact that the results are based on an adult population is suggestive of successful application to employment and vocational training situations, caution should be exercised when using these results to rationalize blanket endorsements of any speech recognition product in these settings. A complete assessment of the demands of a particular job situation, as well as the true limitations of the client, must be weighed carefully before recommending purchase of the equipment by a company or individual.

SUMMARY

In summary, speech recognition technology was found to improve the quality of participants' expository writing. The authors have opted for the benefits of both macro- and micro- analysis of written composition in order to evaluate the technology and its compensatory effectiveness for postsecondary students with learning disabilities. The use of one type of information to verify, explain. and/or understand the findings from other types has proven a most efficacious approach.

Appendix A

"Directions: You will have two hours to plan and write an essay on the topic assigned below. Read the topic carefully. You will probably find it best to spend a little time considering the topic and organizing your thoughts before you begin writing. **DO NOT WRITE ON A TOPIC OTHER THAN THE ONE SPECIFIED.** An essay on a topic of your choice will not be acceptable.

An essay question is given in order for you to demonstrate how well you can write. You should, therefore, take care to write clearly and effectively, using specific examples where appropriate. Remember that how well you write is much more important than how much you write, but do not slight the topic."

Appendix B

WPE SCORING GUIDE

Readers will assign scores based on the following scoring guide. Though the examinees are asked to write on a specific topic, parts of the topic may be treated by implication. Readers should focus on what the examinee does well.

SCORES

6 Demonstrates **clear competence** in writing on both the rhetorical and syntactical levels, though it may have occasional errors. A paper in this category:

--effectively addresses the writing task

--is well organized and well developed

--uses clearly appropriate details to support a thesis or illustrate ideas

--displays consistent facility in the use of language

--demonstrates syntactical variety and appropriate word choice

5 Demonstrates **competence** in writing on both the rhetorical and syntactical levels, though it will probably have occasional errors. A paper in this category:

--may address some parts of the task more effectively than others

--is generally well organized and developed

--uses details to support a thesis or illustrate an idea

--displays facility in the use of language

--demonstrates some syntactical variety and range of vocabulary

4 Demonstrates **minimal competence** in writing on both the rhetorical and syntactical levels.

Demonstrates adequate college writing. A paper in this category:

--addresses the writing topic adequately but may slight parts of the task

--is adequately organized and developed

--uses some details to support a thesis or illustrate an idea

--demonstrates adequate but possibly inconsistent facility with syntax and usage

--may contain some errors in mechanics, usage sentence structure, and diction, but not a consistent pattern of such errors

3 Demonstrates **inadequate college writing.** It is flawed on either the rhetorical or syntactical level, or both. A paper in this category may reveal one or more of the following weaknesses:

--inadequate organization or development

--inappropriate or insufficient details to support or illustrate generalizations

--a noticeable inappropriate choice of words

--an accumulation and/or consistent pattern of errors in sentence structure and/or usage

2 Demonstrates an **inability to control language** on both the rhetorical and syntactical levels.

A paper in this category is seriously flawed by one or more of the following weaknesses:

--serious disorganization or underdevelopment

--little or no detail, or irrelevant specifics

--serious and frequent errors in sentence structure or usage

--serious problems with focus

1 Demonstrates a **clear inability to perform the writing task requested.** A paper in this category:

--may be incoherent

--may be underdeveloped

--may contain severe and persistent writing errors (The writing suggests that the writer does not have control over the conventions of standard written English)

NOTE: **A paper which would be given a "3" because of its flaws on the rhetorical and syntactical levels (e.g., it may digress, ramble be overly general) may on occasion be given an extra point for good writing and passed. This should be done only on those rare occasions when the writing is much better than the treatment of the topic.** Consult your table leader for advice.

Papers which do not respond to the question at all should be given to the table leader. Also, papers that are clearly written by ESL students should be given to the table leader.

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Table 1

Holistic Scores Across Conditions

	SR Higher	**NA Higher**	**Ties**	**Significance**
Speech Recognition vs. No Assistance	**13**	**5**	**8**	**p = .048**
	TR Higher	**NA Higher**	**Ties**	**Significance**
Transcribed vs. No Assistance	**11**	**6**	**9**	(ns)
	SR Higher	**TR Higher**	**Ties**	**Significance**
Speech Recognition vs. Transcribed	**8**	**6**	**12**	(ns)

Table 2

Actual vs. Expected Distribution of Holistic Scores

NO ASSISTANCE

Holistic Score	Learning Disabled (Observed Frequency)	Non-Disabled (Expected Frequency)	Chi-Square	Significance
1-3	35	13.69		
4	14	29.15		
5-6	4	10.16		
Total	53	53.00	44.794	.000

TRANSCRIBED

Holistic Score	Learning Disabled (Observed Frequency)	Non-Disabled (Expected Frequency)	Chi-Square	Significance
1-3	23	13.69		
4	28	29.15		
5-6	2	10.16		
Total	53	53.00	12.936	.002

SPEECH RECOGNITION

Holistic Score	Learning Disabled (Observed Frequency)	Non-Disabled (Expected Frequency)	Chi-Square	Significance
1-3	20	14.20		
4	29	30.25		
5-6	6	10.55		
Total	55	55.00	4.376	.112

Table 3

Correlation of Holistic Scores With Other Measures

Measure	Correlation Coefficient	Level of Significance
Number of Words with Seven or More Letters	.5682	.0001+
Number of Morphemes	.5122	.0001+
Number of Words	.4878	.0001+
Number of Adjectives	.4581	.0001+
Number of Unique Words	.4354	.0001+
Number of Sentences	.4256	.0001+
Number of Propositions	.4092	.0001+
Number of Complex T-units	.3933	.0001+
Number of T-units	.3907	.0001+
Number of Main Verbs	.3764	.0001+
Number of Adverbs	.3475	.001
Number of Words with Seven or More Letters/Words	.2625	.009
Number of Unique Words/sq.rt 2(Words)	.2346	.017
Number of Adjectives/Words	.1554	.082
Number of Complex T-units/T-units	.0539	.316
Number of Adverbs/Words	.0298	.395
Number of Morphemes/T-units	.0398	.361
Number of Words/Sentences	-.0834	.230
Number of Main Verbs/Sentences	-.2230	.023
Number of Unique Words/Words	-.2484	.013
Number of Propositions/Sentence	-.0541	.319
Number of Errors	.1514	.319

Table 4

Factor Analysis of Holistic Scores

Factor 1 (42%) (p=.0001+)	**Factor 2 (12%)** (p=.003)	**Factor 3 (11%)** (p=.04)
Words	7+Letter Words/Words	Main Verbs/Sentences
Morphemes	Morphemes/Words	Main Verbs
T-Units	Morphemes/T-units	
Sentences	7+Letter Words	
Unique Words	Adjectives	
Main Verbs	Adjectives/Words	
Propositions		
Words w/7+Letters		
Adjectives		
Complex T-units		
Adverbs		
Unique Words/Words (-)		

Factor 4 (7%) (ns)	**Factor 5 (7%)** (ns)	**Factor 6 (6%)** (ns)
Complex T-units/T-units	Adverbs/Words	**Words/Sentences(-)**
Complex T-units	Adverbs	**Morphs/T-units(-)**
Adjectives/Words(-)	Adjectives/Words	**MainVerb/Sentenc(-)**
Unique Words/Words(-)	Adjectives	Sentences
		Adjectives/Words(-)
		T-units
		Adjectives(-)

ASSISTIVE TECHNOLOGY FOR POSTSECONDARY STUDENTS WITH LEARNING DISABILITIES: FROM RESEARCH TO PRACTICE[1]

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Running Head: HIGGINS AND ZVI: ASSISTIVE TECHNOLOGY

ABSTRACT

The article reports on the support services program for postsecondary students with learning disabilities at California State University, Northridge at which both student services are offered and formal research on assistive technology is being conducted. It describes the ways in which both clinical and controlled research in the area of assistive technology for persons with learning disabilities were applied to: (1) the selection and prescription of services and compensatory strategies, including assistive technology; (2) the preparation of appropriate curriculum for training on assistive technology for persons with learning disabilities; and (3) the preparation and modification of a written composition curriculum for persons with learning disabilities which emphasizes the use of assistive technology. The authors conclude with an identification of those elements in the setting which promoted the collaboration of both researchers and practitioners to enhance the effectiveness of each professional group at achieving its goals. These included: (1) location of the research staff both geographically and administratively within the service delivery unit; (2) specific opportunities to accomplish joint goals which required intense communication and interaction; and (3) the location of the research staff within a computer laboratory unit invited communication between faculty, staff and students across disciplines in unconventional and informal learning situations.

ASSISTIVE TECHNOLOGY FOR PERSONS WITH LEARNING DISABILITIES:

FROM RESEARCH TO PRACTICE

INTRODUCTION

The relationship of research to practice has been of interest to many fields of scientific inquiry, and perhaps has been a concern since the beginnings of empiricism itself in Western scientific thinking (Ayer 1952). The dichotomizing of a particular method of acquiring "knowledge" (formal research) from how events unfold in their natural context (practice) surely can be traced at least to the ascendence in the sciences (both physical and social) of logical positivism (Wittgenstein 1958, cited by Astman 1984). As Poplin (1984, 1988) and others (Heshusius, 1989; Reid & Hresko, 1981) have pointed out, logical positivism in its strongest form, reductionism, has dominated the paradigms and methodologies expressed in the special education literature in <u>both</u> research (e.g., controlling "extraneous" variables, operationalizing terms) and practice (e.g., task analyses, construction of lesson plans around discrete sub-skills). She argues for the adoption of a holistic approach which implies a methodology of describing the phenomena of learning on the part of a student in the context within which it naturally occurs, again, for <u>both</u> research on persons with learning disabilities and in the practice of facilitating the learning of persons with learning disabilities.

An article by Jack Barton (1987) suggests that three distinct, but often over-lapping meanings are implicated by the types of articles which appear in the "research and practice" literature in any field: (1) The application of the findings of formal research to [medical, clinical, educational] practices in that field; (2) [medical, clinical, educational] practice as a form of research (i.e., as a form of "knowing"); and (3) practice informing research (e.g., changing the focus of future experiments, changing the interpretation of previous findings, etc.). The following paper will attempt to describe a situation in which (1) the findings of "formal" research were rapidly and efficiently adopted by "practioners;" (2) in which practioners conducted "research" based on values other than those of the logical positivist tradition; and (3) in which practice informed future research endeavors. This was accomplished through the aegis of a context in which near-constant collaboration of researchers and practioners was possible. Although many recent papers have appeared which focus on the efficacy of creating collaborative models in enhancing elementary and secondary instruction (e.g., IEP "partnerships," "transition" teams), evaluating instructional programs (e.g., school-based program evaluation models (Jaeger 1989; Olson and Miller 1991)) and in the improvement of teacher training (e.g., Professional Development Centers (Calder 1990)) the authors have chosen instead to provide a description of a context in which professional collaboration was the "natural" state, i.e., already existed and in which, therefore, many of the pitfalls and difficulties described by attempts at creating educational "collaboration" (Garrison and MacMillan 1987; Mosenthal 1984) were successfully sidestepped.

BACKGROUND

Over the last decade, the special education research literature has reflected a gradual realization that the academic difficulties experienced by students with learning disabilities in elementary and secondary settings persist into adulthood (e.g. Chesler 1982; Gerber et al. 1990; Hoffman et al. 1987; Johnson and Blalock 1987; White 1985). Yet in spite of the enduring nature of their disabilities, an increasing number of secondary students are choosing to continue their education. There are over 100,000 students with learning disabilities exiting high school every year (Office of Special Education Programs 1992) and 67% of these have plans to attend postsecondary institutions (White et al. 1982). This great influx of postsecondary students has prompted the development of learning disability support service programs designed to promote academic retention and success (Beirne-Smith and Deck 1989; Vogel 1987).

The Learning Disabilities Student Services Program at California State University, Northridge, was established in 1985 through a State Department of Rehabilitation grant by the Office of Disabled Student Services. It has grown from serving 55 students with learning disabilities during the first year to over 350 at present. Services offered by the Program include diagnostic assessment, the provision of testing accommodations and proctoring, the provision of notetakers, readers and transcribers, academic and career counselling, tutorial services. support groups, orientation information and referral services. Shortly thereafter, under the same roof, the Computer Access Laboratory was founded through a separate grant from the Department of Rehabilitation. It has provided specialized equipment for persons with disabilities of all types including visual, hearing, mobility, communication, functional and learning disabilities and has developed into one of the most well-equipped, (if not the best equipped) laboratories of assistive technology for persons with disabilities in the world. The fortunate pairing of the Learning Disabilities Program and the Computer Access Laboratory under the same administrative and geographic unit brought together for the first time professionals, researchers and experts in the field of assistive technology for persons with all types disabilities, with experts in learning disabilities. It was not long before the staff began experimenting with assistive technology already developed for other types of disability and adapting it for use by persons with learning difficulties. Although there had been numerous applications of computers and other technology for instructional and remedial purposes for children and adolescents with learning disabilities (Chiang 1981; Collins 1990; Jones et al. 1987; Leong 1992; Lundberg and Leong 1986; Olson and Wise 1992; Wise and

Olson 1992), almost nothing appeared in the literature which reported on the use of assistive technology to help postsecondary students compensate for or circumvent their difficulties (Raskind 1993).

RESEARCH INTO PRACTICE:

Practice as a Form of Research

1. ASSESSMENT AND SPECIFIC PRESCRIPTION OF TECHNOLOGY

Before the establishment of the Learning Disabilities Program, the Office of Disabled Student Services had already evolved a philosophy of its own, to provide services and suggest strategies designed to compensate for, rather than correct disabilities, a highly reasonable approach when one realizes that many of the students served by the Office have disabilities (such as congential blindness, paraplegia) that simply cannot be corrected. The Learning Disabilities Program quite naturally adopted a similar compensatory policy over the years. The policy as it stands today, however, is in sharp contrast to that of the field of learning disabilities in general, which has continued to focus on diagnosing and remediating specific deficits. This new emphasis on compensatory strategies by the Learning Disabilities Program arose partially out of the gradual realization that despite decades of considerable efforts at remediation on the part of mainstream special educators, many postsecondary students who had had learning difficulties as children, continued to experience similar problems when faced with the challenge of a rigorous university curriculum. Additionally, there were practical considerations such as time constraints, unavailability of specialized tutors, etc., which made a remedial approach a less attractive alternative. For example, it was not unusual for a student to come to the Computer Access Lab seeking help with a 200 page reading assignment that was expected to be completed in a matter of only two or three days. There simply was not enough time to construct and execute an elaborate phonics program, for example, designed to remediate the reading difficulty.

In any organization, overarching philosophies or policies, such as the compensatory one described above, get spelled out in a series of on-the-ground procedures, which (hopefully) implement the larger goals of the institution. At CSUN, this process began when a student with a learning disability entered the University as a freshman or transfer student and sought assistance from the Office, or when a continuing student suspected he or she might have a learning disorder and requests assessment. He/she undergoes diagnosis and/or evaluation by a Learning Disabilities Specialist. The specialist reviews each file and performs any appropriate assessment testing necessary to determine the student's cognitive and academic strengths and weaknesses. A set of specific compensatory strategies and services is then prepared. Information gathered from the achievement and cognitive assessment measures is shared with the student and the strategies and services suggested are related to each area of strength or weakness. For example, a student with a deficit in auditory memory might be told to keep a pencil and pad of post-it notes handy for writing down assignments, deadlines and other information typically given orally throughout the academic day, how to keep careful and accurate lecture notes, etc.

The emphasis during these assessment "debriefings" is on relating the strategy directly to the academic and cognitive testing information and communicating this to students with simple, direct language which ties the strategy to the observed area of academic strength or weakness. However, the category labelled "learning disabilities" often includes disorders of attention and concentration, organization, memory, and social/psychological functioning, as well as the more academically-oriented deficits in mathematics, reading, writing and spelling.

Also. as students become adults they move into new contexts such as employment, independent living situations and the establishment of their own families. As a result, the attention of the Learning Disabilities Specialists in the Office, as well as in the field of learning disabilities in general, has increasingly focused on non-academically related issues and problems faced by learning disabled students (See, for example, *Journal of Learning Disabilities*, October, 1992; *Learning Disability Quarterly*, Summer, 1993). Consequently, the conferences held with students have come to include compensatory strategies designed to enhance success both inside and outside the classroom, extending to the employment, family and social settings in which students must function. In the example above where the student experiences difficulty remembering information given orally, suggested strategies might include keeping post-it notes handy on the job as well as at school, to jot down all instructions from employers, and might even include avoiding jobs which depend heavily on phone use, such as telemarketing or receptionist positions.

Because of the proximity of the Computer Access Laboratory and the influx of students with various types of disabilities utilizing the technology for different purposes, the Learning Disability Specialists quite naturally began including suggestions for simple technologies, such as the use of a variable speed tape recorder to record lectures or assignments, listening to books on tape, utilizing talking calculators, high-fidelity listening devices. pocket organizers, hand-held spell checkers and other devices. Over time, checklists of suggested services such as proctors, tutors, readers, and transcribers, began to include a separate. ever-lengthening list of technological strategies as well. This list came to include computer technologies such as word processing, organizing programs, spell checkers, grammar checkers and the like.

Finally, as results of the study described below began to emerge, the prescribing of the specific technologies used in the research was added to the list as indications for their use became apparent. For example, a student with below average achievement in reading comprehension might be referred to the Computer Access Laboratory and introduced to the optical character recognition and speech synthesis programs so that particularly difficult material could be scanned in and read back via the speech synthesis/screen review program. Similarly, a student with difficulty in writing and spelling might be introduced to word processing so that term papers could be rapidly generated using the built-in spell checking functions available.

The prescribing of specific technologies eventually extended to include extra-scholastic applications. Assistive technology as a support strategy has the added advantage of addressing some of these non-academic concerns because many of the technologies can be applied across a variety of contexts. For example, in a work setting, assistive technology may release the person with a disability from dependence upon a co-worker to help him or her read written communication. This may reduce unnecessary stress in an important work relationship.

RESEARCH ON SPECIFIC TECHNOLOGIES:

Practice Informing Research

Although the learning disabilities literature reflected a scattering of interest in the use of technology for postsecondary students with learning disabilities (Brown 1987; Collins 1990; Mangrum and Strichart 1988; Scheiber and Talpers 1985; Vogel 1987), little controlled research had been conducted to evaluate its efficacy in compensating for the difficulties faced by postsecondary students with learning disabilities. In the meantime, the field of computer technology continued to generate very promising hardware and software which appeared to be highly applicable to the needs of persons with learning disabilities such as **optical character recognition**, **speech synthesis** and **speech recognition** technology. These three technologies were of particular interest because they are designed to enhance performance in reading and written language, the areas of deficit most frequently reported by adults with learning disabilities (Blalock 1981; Cordoni 1979; Vogel and Moran 1982).

Optical character recognition in conjunction with speech synthesis/screen review technology allows students to scan and convert written text from many sources into computer documents which can then be read by a speech synthesis/screen review program which provides digitalized speech as auditory input while simultaneously highlighting the text on the screen. The speech synthesis/screen review system can also be used to proofread documents generated by students, again using multisensory input from both auditory and visual channels. Speech recognition technology allows students to generate text in the form of a computer document, using speech. The student speaks into a microphone mounted on a headset and the words appear on the computer screen, properly capitalized and spelled, for the most part.

In an effort to address the lack of controlled research directed toward assistive technology and postsecondary students with learning disabilities, the Office of Disabled Student Services at California State University, Northridge sought a grant from the U.S. Department of Education Fund for the Improvement of Postsecondary Education to conduct a three-year study. During the first year of the study the compensatory effectiveness of the three technologies was investigated[2]: (1) the effect of optical character recognition in conjunction with speech synthesis/screen review on **reading comprehension**; (2) the effect of speech synthesis/screen review on **proofreading** efficiency; and (3) the effect of speech recognition on **written composition** performance.

METHOD

Optical Character Recognition/Speech Synthesis and Reading Comprehension

The silent reading portion of the Formal Reading Inventory (Weiderholt 1986) was administered to students under the following three conditions: (1) using optical character recognition/**speech synthesis**/screen review technology; (2) having the test **read aloud** by a human reader; and (3) reading the test silently with **no assistance**.

Speech Synthesis/Screen Review and Proofreading Efficiency

Students were asked to compose a "first draft" of an essay, without proofreading it. The essay was then transcribed into a computer document and divided into three parts, each part being proofread under the following conditions: (1) using **speech synthesis/screen review**; (2) having the selection **read aloud** by human reader; and (3) with **no assistance**.

Speech Recognition and Written Composition Performance

Students were given a "mock" Upper Division Written Proficiency Examination which involved writing an hour-long essay[3] under three conditions: (1) using **speech recognition** technology; (2) using a human **transcriber**; and (3) with **no assistance**. The Upper Division Written Proficiency Exam is the English composition "exit" exam for the University. It is holistically scored on a scale of 1 through 6, with a score of 4 or better being a passing grade and 3 or less a failing one. Readers experienced in scoring real administrations of the test rated all of the essays. After determining the outcome of the study (i.e., the holistic grades on the exams) the essays were further analyzed on 22 measures of **fluency, vocabulary** and **syntactic maturity**. This exploration was done in order to further determine the mechanism by which the technology may or may not have been helpful to students. For example, among other things, the researchers were interested in discovering whether the technology encouraged students to write longer essays, and further, whether longer essays got better scores.

RESULTS

Optical Character Recognition/Speech Synthesis and Reading Comprehension

There were no differences between the means under the three conditions. This was largely due to the fact that the optical character recognition/speech synthesis condition assisted some students greatly but seemed to interfere with the performance of others. Those students with **below average scores** under the silent reading condition **benefitted from use of the technology** while the **above average students showed an interference effect.** A correlation was then computed between the silent reading score and the difference score when using the equipment. This yielded a statistically significant correlation ($p > .001$). A similar, but weaker correlation was found for the "Read Aloud" condition when compared to silent reading ($p > .01$). In short, the findings were that **the greater the disability, the more the technology helped** (Higgins and Raskind 1993, in press [a]).

The researchers suggested that one possible explanation for the above findings was that under the silent reading condition below average readers may have been struggling to decode much of the vocabulary, which interfered with their comprehension of the material (Higgins and Raskind, in press [a]). Under the speech synthesis/screen review condition however, the technology decoded the text for them. This allowed students to effectively circumvent their disability in (presumably) phonlogical processing, permitting improved comprehension. The above average readers, on the other hand, were not struggling to decode the text, but rather were employing the phonological code as a short term memory buffer

(Crowder, 1982) for syntactically complex sentences which appear in the final few paragraphs of the reading test, paragraphs the less proficient readers never reached due to their decoding problems. The auditory input (from either the human reader or the computer) may have interfered with the phonological memory processing these above average students needed in order to unravel the convoluted, multi-clausal sentences in the latter paragraphs (Higgins and Raskind, in press).

Speech Synthesis/Screen Review and Proofreading Efficiency

Students found significantly more errors using speech synthesis/screen review than when proofreading either without assistance or having the essay read aloud to them. The next best method for finding errors was under the "Read Aloud" condition which also showed significantly improved performance over the "No Assistance" condition.

As to categories of errors, the "Speech Synthesis/Screen Review" condition showed students catching significantly more errors in capitalization, spelling, usage and typographical errors than they had without assistance. The "Read Aloud" condition was significantly better at assisting students in catching errors in only one category, mechanical grammar errors. There were no significant differences between conditions for finding punctuation, global grammar problems such as sentence fragments, content/organization difficulties, or errors in style such as mixing metaphors (Raskind and Higgins (in press)). One explanation for the better performance of students using speech synthesis/screen review was that the simultaneous, multisensory feedback provided by the technology enhanced students' ability to process and attend to errors present in the text.

Speech Recognition and Written Composition

Holistic **scores on the essays written using speech recognition** as compared to those written without assistance **were higher** at a statistically significant level ($p=.046$). Scores on essays written using a human transcriber as compared to those written without assistance were also higher but did not quite reach statistically significant levels ($p=.067$). Speech recognition generated essays also scored slightly higher than those written using a transcriber, but these differences were clearly not significant.

In order to compare the performance of learning disabled students to their non-disabled peers, an expected distribution was obtained by making a count of scores on an actual administration of the Upper Division Written Proficiency Examination given to the (presumably) non-disabled population. Percentages of scores were obtained and compared to those of the learning disabled population under the three conditions. As other researchers have found (Gajar 1989; Gregg 1983; Vogel and Moran 1982; Vogel 1985), the distribution of score of the students with learning disabilities were significantly lower than those of the non-disabled students when essays were written without assistance. The essays dictated to a human transcriber were also significantly below the non-disabled sample. However, the distribution of scores on the **essays generated using speech recognition**, although somewhat lower, **did not differ significantly from those written by the non-disabled sample.** The technology appeared to be effective in "leveling the playing field" for the learning disabled students.

Following the determination of the above results, all the essays were analyzed on twenty-two measures of fluency, vocabulary and syntactic maturity. The means of all measures across the three conditions were computed. Statistically significant differences were found in only one measure--**Number of Words with Seven or More Letters** (long words) divided by the total number of words in the essay, **in favor of the speech recognition** condition. This is a particularly interesting finding because a multiple regression analysis of the twenty-two measures revealed that **the best "predictor" of holistic score was Number of Words with Seven or More Letters.** Correlation coefficients were also calculated for the twenty-two measures of fluency, vocabulary and syntactic maturity. Many of the measures related to **fluency** (length of the essay) proved to be significantly correlated with holistic scores. A factor analysis revealed six identifiable factors, three of which were significantly correlated with holistic scores: Factor One contained many measures related to **fluency** (length of essay); Factor Two contained measures related to vocabulary and **morphological complexity**; and Factor Three contained measures of Number of **Main Verbs** and Main Verbs per Sentence, a rough approximation of sentence complexity. (Higgins and Raskind, in press [c]).

RESEARCH INTO PRACTICE:

The Application of the Findings of Research to Practice

2. IMPROVING WRITTEN COMPOSITION WITH ASSISTIVE TECHNOLOGY

Part of the mandate of the grant was to train the remainder of the students with learning disabilities who had not participated in the first year of study. The problem was devising a training program which would provide sufficient motivation for students to commit the time and energy necessary to learning the new technologies. The researchers knew from the learning disabilities literature, as well as from working with students, that written composition was one of their biggest concerns. From the study in which students wrote a "mock" Written Proficiency Exam, the investigators knew there was great anxiety about taking the actual exam. Many students reported that they had volunteered for the project expressly to get practice in composition skills which might help them pass, to explore whether they might actually use the technology to take the exam, and to get feedback on the acceptability of their writing. Several expressed that they had persisted with the formal part of the study which involved taking all three mock exams under the conditions described above because they were "learning" so much about writing.

Interestingly enough, because it was a controlled study, during the training on the equipment and throughout the writing of all three, essays under experimental conditions, the researchers were careful to give no instruction in writing whatsoever! (This would have confounded the results, of course.) But what the investigators did do was tell students from the outset of the study that they would be taking practice exams under three conditions and that the staff would be sharing with them after the formal research how they had performed using the equipment, using transcription and writing alone. The researchers also promised share the general findings of the study as to particular variables that correlated highly with holistic scores.

In addition to being careful about not instructing or editing their work, the investigators inadvertently did another "right" thing. In an effort to keep the students coming back to finish the study, at the beginning and end of each session the staff thanked them heartily for putting in so much time and effort in their writing, and attempted to keep the encounter a generally positive one. If the researchers noticed the student had struggled over finding the right word for something, they would comment on it and thank her/him for not giving up. Or if a subject had had trouble getting started the staff might share an experience from their own writing. For example, one researcher who had written a mystery novel shared not being able to get into the proper "mood" to "commit a murder." Sometimes during a transcription a researcher would get a student who could barely get out a phrase without correcting him or herself. A typical comment after the session might include, "I hate it when I can't turn off my censor long enough to even get a sentence out." These often began quite interesting discussions on writing as a process.

The researchers had intended to simply assist students in recovering from what was frequently an anxiety-producing experience for them. However, the staff members have come to believe much more got communicated. The students saw for the first time that even published writers struggle to find words and sometimes can't get started, which may have helped them to dispel myths common to many inexperienced writers. This in turn may have allowed them to distinguish more clearly between those difficulties in their compositions that were due to their disability from those due to inexperience and/or lack of practice. Additionally, by focusing students' thinking about writing on the process and content rather than the mechanical errors in the product, students may have been able to see the strengths as well as the weaknesses in their written language, perhaps for the first time.

The original students came back many times after the study with assignments and papers asking for a similar kind of assistance. The researchers again attempted to keep these encounters positive, focusing on the writing process rather than meticulously editing the product. After their participation in the formal part of the study was completed, the discussions with students included the content and organization of their papers as well. Again, in addition to sharing with the students their individual results on the formal part of the study, the composite research data from the study was passed on to them as it became available. The investigators observed this information being used by the students to individually improve their writing and kept careful anecdotal records of these instances. Additionally, as new results were shared with the staff, trainers in the Computer Access Lab and those active on the grant modified methods of "instructing" (coaching?) learning disabled students on the computer equipment and modified the curricula of the two mini-courses as appropriate. Again, anecdotal notes were kept of such incidents and contributed to the data base used to reach final conclusions about the efficacy of the technology in assisting students with compensating for their disabilities.

What were those general findings communicated to students and staff? First, an extremely powerful variable was **fluency**, or length of the essay. In short, the students were not writing enough, even though they were given extra time to do so. Often they had not taken the full time allowed. They were simply running out of things to say. Their writing was constrained, and the **vocabulary** had become truncated and simplistic. A strategy frequently reported by the students was that when they wanted to use a word they did not know how to spell, they would substitute a "baby" word in order to avoid the embarrassment of a misspelling. One can well imagine that the effect of this strategy over time, would be to restrict further and further their written vocabulary.

The emotional component of these tendencies toward constriction and truncation, as compared to the role their actual disability played was unknown from a statistical point of view. But from what the investigators had observed during the formal part of the study, many students showed a doubling or trebling of the number of words written, regardless of the method of generating the essay (transcribed, without assistance, or using speech recognition).[4] This increase occurred after only three, meager writing experiences to which the students had been exposed during the course of the formal study, **under the condition that they received no editing, correcting or instruction whatsoever**, and with the only commentary on their work being limited to obvious process-oriented observations. The researchers suspected, therefore, that the emotional component of this characteristic lack of fluency was quite high.

Many of the students had had long histories of failure with writing, years of getting back papers that looked like road maps, with red ink everywhere. The emphasis on mechanics, spelling and punctuation, had left them ashamed and discouraged about their writing. Their response had been to avoid writing whenever possible. This began the downhill spiral of falling further and further behind their peers due to lack of practice, which increased their feelings of shame and further increased avoidance of the activity.

On the other hand, the use of computer technology as an assistive device to increase productivity appeared to have a liberating effect on students, releasing them from the tyranny of a severe spelling disability, for instance, with the touch of a single command key. Specifically, one of the findings of the research was that the use of speech recognition technology directly encouraged the expansion of more mature and complex vocabulary (longer words). This occurred because the program made more accurate guesses at long words spoken into the system than short words, since more phonetic information was available in the longer, multisyllabic words. In an effort to get the program to stop stumbling quite so much, students selected longer and longer words over time.

The Writing "Mini-courses"

Because of the general philosophical emphasis within the Office and direct experience with the students during the study, the investigators decided to continue to stress the use of technology assistively, rather than remedially or instructionally. The courses were "advertised" as an opportunity to learn how to use technology to enhance writing. The staff sent out flyers for two new "mini-courses," one which would focus on using the technology for passing the Upper Division Written Proficiency Examination and one which would focus on Writing a Term Paper (another frequently-reported "high anxiety" task) using technology.

The response was overwhelming, literally. The investigators soon found themselves unable to handle both the numbers of students requesting training and the other research demands required by the grant. Two new Instructional Support Specialists were hired part-time to work one-on-one with the students.

In selecting the Support Specialists, the researchers considered choosing "techie" types, persons highly familiar with the computer technologies involved. But these people first of all, were impossible to find; the only people who were trained on speech synthesis, optical character recognition and speech recognition, were already working in the Computer Access Laboratory providing assistance to students with other types of disabilities. The investigators also considered special education majors in learning disabilities, perhaps graduate students, but decided against this because their focus would be on instruction and remediation, an approach that was already available in other settings within the University (Learning Resources Center, Tutorial Services), and which had not been particularly successful with assisting postsecondary students with learning disabilities to improve their writing.

The research staff finally settled on Creative Writing and Composition graduate students as a pool of possible candidates. First, they were used to working with inexperienced writers in English composition courses. As mentioned above, the largest component of the problem faced by the postsecondary students with learning disabilities was inexperience caused by writing avoidance, rather than their disability directly. Consequently, the learning disabled students shared much with the population of students with whom these graduate students in composition had already been working. They were also accustomed to working with postsecondary students, planning activities and curricula appropriate for adults, whereas had we chosen special education teachers, there would have been a necessity to monitor closely the types of materials and techniques they tried to use and adapt from their own work with elementary and secondary students.

Secondly, these instructors were capable of communicating the joy of writing they themselves experienced, as well as their fascination about and experimentation with writing as a process. They were well-aware that the "back to basics" approach with its emphasis on teaching rules in isolation from actual composition, critical editing and meticulous attention to the mechanical aspects of writing, were destructive to the spontaneous generation of written material which the formal study indicated should be encouraged. They were able to recognize talent, sometimes well-disguised amid many mechanical deficiencies, and could focus on the strengths of the students' papers. Because they were actively involved in the writing process themselves on a daily basis, they could also help to dispel some of the myths inexperienced writers have about accomplished writers, i.e., that they write quickly and near flawlessly without having to rewrite or edit their work.

Third, they were experienced readers of actual administrations of the proficiency exam and in judging holistically scored compositions. They knew what was expected and were used to looking at the entire essay rather than focusing on one aspect such as mechanics, organization, or usage.

What emerged in the mini-courses was:

1. An approach that stressed the **assistive use of technology** (rather than remedial or instructional);

2. That encouraged **fluency, content and vocabulary expansion**;
3. That **focused on strengths** in the students' products, allowing the technology, as far as possible, to contend with weaknesses such as spelling, punctuation, etc.;
4. That **focused on process** and content rather than the mechanics of the written products;
5. That utilized a **one-on-one setting** to minimize embarrassment and engender trust;
6. That **utilized creative writers** and composition personnel who could communicate the joy and benefits of the writing process;
7. That **provided instruction** only in the form of information concerning the administration of the Upper Division Written Proficiency Exam or information regarding the mechanics of citation, etc., in the case of the Term Paper Mini-course **only as students requested** it or as it emerged as a concern of the students while working on their projects.

Students typically met with Instructional Support Specialists in one-to-one sessions lasting between one and two hours. The first session with a student was spent in orientation which involved a short tour of the Computer Access Laboratory, an explanation of the purpose of the courses (i.e. to learn to use technology to enhance writing performance and work around areas of disability), communicating the results of the formal study (e.g., fluency and use of expanded vocabulary enhanced scores, number of mechanical errors were not highly correlated with holistic scores), explicating the seven goals mentioned on the previous page, and arranging the next session at a convenient time for the student and specialist. At subsequent sessions, students usually brought in their own classroom projects, assignments or papers and received training on various pieces of technology as appropriate for the project and the compensatory needs of the student. (For those with no specific project, a set of "motivational" writing topics or projects was assembled.) Computer training included instruction on the operation of several word processing programs, the three technologies targeted in the study, and two organization/outlining programs. The number of sessions ranged from as few as two, to as many as fourteen sessions, with an average of 4.8 hours of consultation following the orientation session.

Participants in the first year's formal study as well as those who received training on the technologies during years two and three showed several positive long-term academic outcomes. Passage rates on the Upper Division Written Proficiency Exam showed significant improvement for the trained group. Of the 140 participants (80 from the formal study in year one and 60 from years two and three mini-courses) 42 took the exam and 40 passed on their first attempt (95%). The overall passage rate for the non-disabled CSUN population is 75%; passage rates for students with learning disabilities registered with the Office of Disabled Students Services in years previous to the beginning of the study were approximately 50%, as was the rate for a matched group of learning disabled students who had not received training (52%)[5]. Their grade point averages for courses with heavy reading and/or composition requirements were significantly higher ($p > .05$), although these gains were not sufficient to increase overall GPAs so that they reached significance.

The most striking findings were in the area of retention rates. Only two students left school or were disqualified out of the 140 participants over the three-year period (1.4%). This result was impressive considering that the attrition rate for non-disabled students at the

University is 48% over four years (CSU *Stateline*, 1994) and was 33.6% over the same three-year period for the matched group of learning disabled students who had not received training. Graduation rates were 11% per semester for study participants and 23% for mini-course participants (primarily juniors and seniors) as compared to 5% for the matched controls (Each participant was matched with another learning disabled student who had entered the University during the same semester.)

There were several changes in the academic behaviors of the study and mini-course participants. Using pre and post-study questionnaires and logon records from the Computer Access Lab, it was determined that there had been a 78% increase in the use of assistive technology in general. Further, more than 75% of the respondents reported that they had put computers to use for academic purposes other than composition, such as note-taking, organizing course content, outlining reading material, and time and deadline management. Ninety percent reported extending the use of computers into at least one non-academic setting, including actual employment assignments, job searching, and for recreational and social purposes. There was a 22% decrease in the use of other services, both within the Office of Disabled Student Services and campus wide. Changes in attitudinal and affective variables were assessed using the Dimensions of Self Concept (Michael, Smith & Michael, 1989). Significant differences were found on three of the five scales: Identification vs. Alienation, Leadership/Initiative, and Academic Interest/Satisfaction. Content analysis of free responses to questionnaire items confirmed these findings and further indicated that use of assistive technology and/or participation in the study was responsible (at least in the minds of the participants) for the improvement in their self-concept. Forty-six percent of the respondents uttered the reply, "...the computer has changed my life [for the better]," and

80% expressly stated feeling, "...better about myself." when asked whether participation in the study had been useful to them.

SUMMARY, CONCLUSIONS AND IMPLICATIONS

Examples were given from a three-year research project of the ways in which the goals of both research (to advance knowledge in the field) and practice (to provide and improve service to recipients (patients, clients, students) in the field). The examples were chosen accordance with Barton's (1987) classification of the possible relationships between research and practice: (1) **The application of the findings of research to practice**--The findings of the first year of study that fluency and vocabulary complexity enhanced scores was used to develop a curriculum for mini-courses focused on the use of computer technology to improve written composition skills; (2) **Practice as a form of research**--The practice of prescribing compensatory strategies based on assessment and diagnostic information was extended to include specific technologies; and (3) **Practice informing research**--The above diagnosing and prescribing of less sophisticated technological strategies led to the formulation of the research proposal itself on the specific technologies studied.

A brief perusal of recent journals indicate that the field of learning disabilities embraces both the goals of research, to further the state of knowledge concerning learning disabilities, and of practice, to provide and improve services to persons with learning disabilities. The authors described a setting in which the collaborative efforts of researchers and practitioners seemingly enhanced the contribution either professional group could have made alone.

What was it about the particular setting which made the above collaboration possible? Hopefully, the readers will benefit from the following attempt to identify the attributes of the setting which most apparently promoted such collaboration:

(1) First, and most obviously, the research staff was geographically and administratively located in the midst of the service delivery unit, i.e., the Office of Disabled Students Services. The mere proximity of research and service professionals allowed them to take advantage of many communicative contexts, from formal staff meetings to casual discussions over lunch. Second, the positioning of incoming research staff administratively, placed them on an equal footing with the existing service delivery staff so that there were no artificial organizational barriers to establishing open communication, no ambiguity as to the researchers and practitioners relating to one another as peers. Second, locating the research team at the geographic site of service delivery allowed them to observe not only the day-to-day provision of services by practitioners, but the students requesting and receiving them. Last, the students themselves were close at hand for researchers to communicate with and observe while meeting the everyday demands of a rigorous academic curriculum. This was especially helpful in gathering information on long-term progress necessary to meet the three-year longitudinal goals of the research.

(2) In addition to the above advantages which might occur by locating researchers on the site of offices of disabled student services on most college campuses, there were a few unique conditions that existed only at CSUN's Office of Disabled Students Services that further enhanced collaboration. First, there was a yearly CSUN-sponsored joint project in which all staff, clerical, professional, service providers and researchers were participants. The Annual Technology Conference for Persons with Disabilities gave the professional staff at least one opportunity a year to work together to prepare exciting presentations of research findings and current service innovations, orgainized around the theme of improving technological benefits

to persons with disabilities. By making preparations for dual presentations, professionals from both research and practice were forced to listen carefully to each other's point of view, to discover differences and similarities, and to appreciate the advantages of the approach of other professionals to their own specific circumstances and settings. These generated noticeable and profound shifts in attitude by both researchers and practitioners, in a comfortable and non-threatening, way. Although no conscious attempts were ever aimed at facilitating change, of setting up the position of researchers or practitioners as a "change agents," almost effortlessly, the new point of view could be incorporated into a larger theoretical position which would encompass both the goals of research and those of service delivery. Additionally, because of the world-wide reputation of CSUN's program, many invitations to speak and present papers were offered to professional staff, and these also assisted them in exposing them to new audiences outside their own field. These included chances to speak to employers, manufacturers, technology development engineers, rehabilitation professionals, educators outside special education, and administrators of other disability service offices for postsecondary students with learning disabilities. Last, there was also a tradition at the Office of Disabled Students Services as it grew from small to large, of professionals filling in for one another to assist students and accomplish other ODSS goals. This wonderful habit of exchanging tasks, allowed all professionals the opportunity to actually experience conducting the work of their fellows from other specialties. Researchers might find themselves proctoring exams for a blind or administering an IQ test for a motor impaired person. Performance differences between these students and the learning disabled population often provided new insights and posed new research questions. To "return the favor," practitioners might assist with reading essay to check the reliability of test results or other research tasks. This often piqued curiosity about the research and exposed practitioners to quantitative techniques of measuring performance to verifying their own "hunches" and intuitions about diagnostic or treatment variables.

Because of their emersement in the day-to-day life of service provision, researchers were led away form extreme reductionist or mechanistic theoretical paradigms to plan for the next step in research. The gradual development of a more holistic perspective kept a check on veering too far from natural contexts and the "real life" demands placed on students and service providers. Further, it allowed researchers to seize opportunities for using a variety of data collection techniques to obtain final results. For example, data bases set up to generate reports to oversight management were used to determine changes in use of services on campus by participants in the study, and to generate matched controls for comparison. The development of a more contextual theoretical framework on the part of researchers and the increased use of non-experimental quantitative data gathering allowed researchers to not only collect more qualitative information but to use such data to verify weak or inconclusive quantitative results.

(3) The research was conducted at a computer technology center; the Computer Access Laboratory is part of the Office of Disabled Student Services. The learning of computer technology itself, wherever it occurs on campus, appears to be conducive to collaboration. First, it breaks down role barriers. The "C" student can become the expert when teaching his professor a new strategy for winning a computer game, for example. Second, although outside trainers are occasionally hired to teach a new software product to a large group, this type of formal instruction is the exception. More typical is the lone user, working his or her way through a new program with no more help than a poorly written manual of instruction,

or occasional troubleshooting by a lab assistant. Endemic to the field is the use of non-standard learning techniques and groupings and non-lecture formats. Also, such computer centers attract students and staff from virtually every discipline as they struggle to keep current on technological advances in their field. All arrive in the same state of relative ignorance as to the computer technology they are there to learn or use. This forces them, from time to time, to seek assistance from whoever is present, be it an English professor typing a novel or a finance student operating a sophisticated statistics program. Often, cross-discipline exposure to techniques and content result. This was also the case at the Office of Disabled Student Services, where the original intent of mastery of the technology often promoted further cross-discipline communication, in this case, communication between researchers and practitioners.

In conclusion, the authors found that the information exchange made possible by both conducting controlled research and providing service delivery within the same setting proved highly beneficial for all the professionals involved in the various endeavors. The high rate of success of the students would indicate that on-site research activities enhanced the effectiveness of both research and service delivery professisonals so that more effective planning and policy making could be achieved for the population of postsecondary students with learning disabilities.

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FOOTNOTES

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[2]During years two and three, long-term academic outcomes, behavioral and affective changes and cost effectiveness were investigated.

[3]Non-disabled students are given one hour to complete the essay. Students with disabilities, including those with learning disabilities, are granted extra time (up to one hour more).

[4]The conditions under which the essays was randomly assigned so that changes in variables such as length of essay were distributed equally over all three conditions.

[5]Each student in the study and who had participated in the mini-courses was matched on age, sex, ethnicity, SES, and major with another student with learning disabilities who had entered the University during the same semester.

Assistive Technology for Postsecondary Students with Learning Disabilities: An Overview

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Running head: TECHNOLOGY & POSTSECONDARY

Abstract

The number of postsecondary students with learning disabilities has increased dramatically over the last several years. This increase, coupled with federal legislation mandating "academic adjustments" for students with disabilities, has prompted the development of postsecondary learning disability support service programs. One support service which has begun to attract considerable attention is assistive technology. The purpose of this paper is to provide an overview of assistive technology as it relates to postsecondary students with learning disabilities by: 1) briefly tracing the development of assistive technology service for postsecondary students with learning disabilities; 2) identifying basic models of assistive technology service delivery and specific services; 3) providing a description of specific assistive technologies; 4) reviewing research on the effectiveness of assistive technology with postsecondary learning disabled students, with a focus on the authors' three-year federally funded study; and 5) concluding with a summary and recommendations.

Since 1985 the number of students with learning disabilities (LDs) entering postsecondary programs has grown faster than any other disability classification (American Council on Education, HEATH Resource Center, 1992). Although statistics are not readily available as to the precise number of postsecondary students with LDs, data from the American Council on Education (1992) and the National Center for Education Statistics (1987) suggests that the figures range from approximately 160,000 to 300,000. In fact, according to Jarrow (1987), Executive Director of the Association of Higher Education and Disability (AHEAD), students with LDs are the "single largest contingent of students with disabilities being served on American campuses (p. 46)."

This burgeoning population of students with LDs, coupled with federal legislation (Section 504 of the Rehabilitation Act of 1973, Subpart E) mandating "academic adjustments" for students with disabilities, has prompted postsecondary institutions to develop LD support service programs aimed at promoting academic retention and success (Beirne-Smith & Deck, 1989; Vogel, 1987; Vogel & Adelman, 1993). Although the specific services offered by individual programs vary (Shaw, McGuire & Brinkerhoff, 1994; Vogel, 1993), programs often provide readers, notetakers, tutors, counselors, academic advisors, advocates, compensatory strategy instruction, diagnostic assessment and test-taking modifications. In addition to the above services, postsecondary LD support programs are offering increasing levels of "assistive technology" (sometimes referred to as "auxiliary aids" or "adaptive technology") (Bryant, Rivera & Warde, 1993; Mellard, 1994; Raskind & Scott, 1993; Rothstein, 1993; Shaw, et al., 1994; Adelman & Vogel, 1993).

According to the Technology-Related Assistance Act of 1988 (P.L. 100-407), an assistive technology device refers to "any item, piece of equipment, or product system, whether acquired commercially off-the-shelf, modified, or customized, that is used to increase, maintain or improve the functional capabilities of individuals with disabilities." For purposes of this paper, assistive technology is further delineated as any technology which enables an individual with an LD to compensate for specific deficits. In some instances the technology may assist, augment or supplement task performance in a given area of disability, while in others, it may be used to circumvent or "by-pass" (not remediate) specific deficits entirely.

A review of the approximately 1,000 listings in Peterson's Colleges with Programs for Students with Learning Disabilities (Mangrum & Strichart, 1992) indicates that virtually all LD support service programs provide some form of assistive technology (listed under "auxiliary aids") to their students. These assistive technologies are most likely to include "basic devices" such as tape recorders, word processors, spell-checkers and calculators. Although to a much lesser extent, many programs also offer speech synthesizers, optical character recognition (OCR) systems, listening aids and speech recognition systems.

The purpose of this article is to provide an overview of assistive technology as it relates to postsecondary students with LDs. Specifically, this paper will: 1) briefly trace the development of assistive technology service for postsecondary students with LDs; 2) identify basic models of assistive technology service delivery and specific services; 3) provide a description of specific assistive technologies; 4) review research on the effectiveness of assistive technology with postsecondary LD students, with a focus on the authors' three-year federally funded study; and 5) conclude with a summary and recommendations.

The Development of Assistive Technology Service Delivery for Students with LDs in Postsecondary Settings

It is difficult to precisely determine the factors leading to assistive technology use with postsecondary students with LDs. The entry of assistive technology into postsecondary LD programs is undoubtedly the result of multiple forces and influences both within and outside of postsecondary institutions, and reflects the growing interest in and use of technology in society as a whole. Such factors likely include the growth of technology (e.g., academic computing, electronic information systems) on postsecondary campuses, the tremendous influx of persons with LDs into postsecondary settings, combined with federal legislation which mandates "academic adjustments" (including the availability of auxiliary aids), as well as increased financial and personnel demands of providing support services to the ever increasing population of individuals with LDs (Vogel, 1987). The provision of assistive technology to students with other disabilities (e.g., tape recorders, OCR) may also have acted as a catalyst. Additional factors may include the growing awareness on the part of technology developers/manufacturers (e.g., Xerox/Kurzweil, Humanware, that subsequently developed LD-specific products) of the need for, and vast potential of the LD market, the passage of the Americans with Disabilities Act of 1990, Section 508 of the Rehabilitation Act of 1973 (amended the Act in 1986), the Individuals with Disabilities Education Act of 1990 (which now includes specific mention of assistive technology), and the Technology Related Assistance Act of 1988.

There are a number of other traceable "forces" which appear to have made a major contribution toward promoting the use of assistive technology, although it is impossible to determine the exact manner in which they influenced postsecondary LD programs, nor their degree of impact. These forces include the establishment of the High-Tech Center for the Disabled of the California Community Colleges Chancellor's Office in 1986 which led to a network of over 100 High-Tech Centers for the Disabled. These centers were designed to provide students with disabilities, including LDs, "training in, and access to, supportive technologies that [would] allow them to compete effectively in both academic and workplace environments" (Brown, Norris & Rivers, p. 389) and also establish a research, evaluation and training facility for directors of disabled student service programs at all of the 107 California community colleges. Project EASI (Equal Access to Software and Information) founded in 1988, as a special interest group of EDUCOM (a consortium of over 600 colleges and universities and approximately 100 corporate associates), has also played a predominant role in promoting the use of assistive technology for postsecondary students with LDs. This group has acted as a leading resource to the higher education community on developing computer support service for persons with disabilities through conducting seminars, on-line workshops, and developing numerous publications on "adaptive computing technology" including technology for persons with LDs.

The California State University, Northridge (CSUN) Center on Disability has also impacted the area of assistive technology and postsecondary students with LDs by initiating (in 1985) one of the first conferences on technology and disability, and creating a specific topical strand on assistive technology and postsecondary students with disabilities. This provided a forum for some of the first presentations in the area. The CSUN program also established a comprehensive LD support service program and Computer Access Lab in 1985 which provided a vast array of assistive technology to students from a number of disability categories, and the opportunity to intensively explore the potential benefits of numerous assistive technologies with postsecondary LD students. These initial informal investigations set the stage for a series of formal research studies on the effectiveness of several assistive technologies with postsecondary students with LDs which will be discussed later in this paper.

In addition to the above mentioned organizations and programs, Murphy (1991), in a report from the National Council on Disability, has identified seventeen "exemplary technology-support programs" for postsecondary students with disabilities, nine of which indicate services for students with LDs . These programs have acted as models in the area of assistive technology and postsecondary students with LDs and include Disabled Student Services, University of Wyoming; the Assistive Technology Center, University of Minnesota; the Disabled Computing Program, University of California, Los Angeles; The Office of Services for Students with Disabilities, University of Nebraska; the Adaptive Computing Technology Center, University of Missouri; the Adaptive Technology Laboratory, Southern Connecticut State University; and the Center for the Vocationally Challenged, Grossmont Community College. The two remaining programs include those already discussed, the California Community College High-Tech Center, and the CSUN program.

Certainly, many other programs, organizations and individuals (e.g., AHEAD, HEATH Resource Center) have contributed to the area of assistive technology for postsecondary students with LDs. Unfortunately, space limitations do not permit further discussion. The authors apologize to any parties that may have been omitted.

Delivery of Assistive Technology to Postsecondary Students with LDs

Assistive technology service delivery models and services vary considerably between institutions. Although no nationally representative random sample of assistive technology service delivery for students with LDs currently exists, basic models and practices can be discerned from a review of limited literature (Brown, 1987; Burgstahler, 1992; Cutler, 1990; EASI, 1991; Horn, 1990; Murphy 1991; Raskind & Scott, 1993). First of all, the institutional office or department charged with managing assistive technology services may vary from campus to campus. In most instances the provision of assistive technology is managed by either disabled student service offices, academic/departmental computing services, or the institution's central computing department. Murphy (1991) indicates that out of the nine "exemplary technology-support programs" reporting LD services, four programs were coordinated by the office of disabled student services, four by the central computing department and one program which was "self-managed." Similarly, Burgstahler (1992) in a survey of technology services for students with disabilities at 1,200 postsecondary institutions, found that the departments most likely to manage computing services were, in descending order, disabled student service offices, central computing services and departmental computing services.

The location of the assistive technology may also differ between institutions, with some programs distributing assistive technology throughout the campus (distributive model) at existing computer sites, and others providing assistive technology at a central location. Proponents of the distributive approach assert that it is more in line with federal regulations mandating integration of students with disabilities, and that it will help ensure greater access to the full range of campus-computing resources, while advocates of the "centralized model" argue that housing assistive technology services in a central location results in higher student satisfaction and success, as well as a higher degree of efficiency in the delivery of services (Burgstahler, 1992). According to Burgstahler (1992), the majority of postsecondary disabled student service providers endorse the distributive model.

In addition to the management and location of assistive technology, programs may also vary considerably in regard to the specific services provided. These services include: a) the range of available assistive technologies (e.g., OCR, spell checkers, word prediction, abbreviation expansion, speech recognition, outlining, speech synthesis); b) the specific brands or models of assistive technology provided (e.g., DragonDictate™ vs. Kurzweil Voice™ speech recognition); c) the extent and model of training/support provided; d) the background/expertise of the personnel providing training/support; e) the degree of technical support offered to students; f) the presence of "user groups;" g) the existence of an equipment loan program; and h) provisions for funding. Again, there is no published data to precisely determine the exact assistive technology services provided to postsecondary students with LDs across the nation.

Overview of Assistive Technologies

This section will present an overview of assistive technologies currently available for assisting adults with LDs (space limitations will not permit a discussion of all technologies).[1] The technologies discussed in this section have been suggested for use with postsecondary LD students by a number of authors (e.g., Brown, 1987; Bryant, et al. 1993; Raskind & Scott, 1993; Shaw, et al., 1994). Recommendations are based primarily upon case studies and "clinical observations" and are not necessarily supported by formal research (research on assistive technologies will be discussed in the next section). The authors of this paper have utilized these technologies with approximately 400 students over an eight year period in the Learning Disability Program and Computer Access Lab at CSUN (part of the Office of Disabled Student Services [ODSS]).

Technologies will be discussed relative to the difficulties experienced by postsecondary students with LDs and grouped together according to the area of disability the technology is intended to circumvent. Several of the technologies have more than one application, and will be listed under more than one heading. It is important to stress that not all the technologies discussed will be appropriate for all students with LDs, and that a technology that might be

[1] This section draws heavily from previous publications: Raskind & Scott (1993) and Raskind (1993, 1994), and is updated to reflect the most current technological developments.

extremely valuable to one person might be ineffectual, or even detrimental to another. Therefore, it is imperative that technologies be chosen for use relative to the particular individual (strengths, weaknesses, interests and experiences), function to be performed and context of interaction.

Written Language

Word processing. The written language difficulties of adults with LDs have been well documented (e.g., Gregg & Hoy, 1989; Hughes & Smith, 1990; Johnson, 1987; Vogel, 1985). In fact, Blalock (1981) asserts that between 80% and 90% of LD adults exhibit written language disorders. Several researchers (e.g., Collins, 1990; Primus, 1990) have found word processors valuable in helping persons with LDs compensate for written language difficulties. Unlike the conventional methods of writing with pencil and paper or typewriter, word processors enable LD users to write without having to be overly concerned with making errors, since text can be corrected on-screen prior to printing.

When not preoccupied with the "mechanical" aspects of writing, persons with LDs have a greater opportunity to focus on "making meaning." This is of particular importance for those individuals who have developed a fear of translating their thoughts into written language as the result of a history of writing problems and the criticism that often follows. Knowing that they can simply "generate" language and correct errors later, may reduce their anxiety, "liberate" their writing abilities, and ultimately facilitate written expression at a level commensurate with their intelligence. Furthermore, word processing may lead to "neater and cleaner" documents, which may in turn help students foster a sense of pride in their written work and enhance the image they have of themselves as writers.

Although the level of complexity of word processing programs varies considerably, most

LD postsecondary students should be able to learn basic operational procedures within three to four hours. The cost of word processing software ranges from approximately $200 - $300. The cost of a computer to run the software and of sufficient quality necessary to meet the needs of a postsecondary LD student, can be purchased for around $1,000 - $2,100.

Spell checking. Many adults with LDs have written language disorders which include difficulty with spelling (Johnson, 1987; Vogel & Moran, 1982). The use of spell checkers, (generally included in word processing programs) may help compensate for such problems since they permit the user to check for misspelled words within a document before a final copy is made. Spell checkers match the words in a document against words in the spell checker's dictionary, and if a match is not found, the user is alerted by a visual or auditory cue and is presented with a list of words from which to choose the correctly spelled word. The user selects the correct word and the computer automatically corrects the misspelled word in the text. Some spell checkers alert the user to spelling errors while typing (which may be disruptive to some students), while others check for mistakes after the document has been completed. For a comparative analysis of spell checking programs for use with persons with LDs, refer to Cutler (1990).

Selecting the "correct" word from a list of options can be a difficult task for many LD students. Cross-checking the words for synonyms in the word processor's thesaurus or dictionary (if available) can assist in the selection process. It should be noted that only misspelled words will be picked up with a spell checker. The incorrect use of homonyms (e.g., there and their) that plagues many LD writers will not be "red flagged."

In addition to spell checkers that are part of word processing programs, there are also battery operated stand-alone spell checkers that are available in desktop and pocket sizes. Basic units will simply verify and correct spelling on an LCD display, while more sophisticated devices provide dictionaries and thesauruses. Some of these units are now equipped with speech synthesizers, which enable the user to hear, as well as see, the word in question, definitions, synonyms and help messages. Prices range from approximately $30 for the more basic checkers, to $500 for more sophisticated units with speech synthesizers. These products are relatively simple to use and generally require no more than fifteen minutes to one hour to learn to operate.

Proofreading programs. LD adults with written language problems may also benefit from the use of proofreading programs. These software programs (now included within some word processors) scan word processing documents and alert users to probable errors in punctuation, grammar, word usage, structure, spelling, style and capitalization. Most of these programs can be used to either mark probable errors, or mark the error along with a commentary (e.g., "Be sure you are using 'is' with a singular subject."). Many programs include on-line tutorials which allow the user to study the language rules checked by the program.

It is important to stress that proofreading programs are not completely accurate, and on the average pick up only about 25% of grammatical errors and 80% of "objectionable phrases" in a document (Frankel, 1990). They may also make incorrect suggestions, prompting the user to correct elements of writing that are not really incorrect. In addition, some LD individuals may find these programs demeaning, with the technology playing the role of an intolerant "electronic teacher," criticizing them and possibly intensifying feelings of incompetence and low self-esteem.

Proofreading programs can usually be purchased for under $100 and require about one hour of training before they can be used reasonably well.

Outlining/"Brain storming" Although some individuals with LDs may have great ideas in their "heads", getting them down on paper may be another story. Writing that first word or sentence can be an insurmountable task; even if the person can get started, there may be difficulty determining how to proceed. Many persons with LDs may have difficulty organizing a paper with regard to topics, categories and sequence (Johnson, 1987). Outlining programs (now included in many standard word processing programs) may help with such difficulties, since they enable the user to "dump" information in an unstructured manner, information which can subsequently be placed in appropriate categories and order. Although each program has it own features, generally, the user types in any idea or thought on a specified topic without regard to overall organization. By using a few simple key strokes (or mouse, pointing and clicking), the outlining program will automatically create the Roman numerals for major headings, and letters and numbers for subordinate headings. The user need not be concerned with order, levels of importance, or categories, since text can be easily moved at a later time. Once basic ideas have been written down, those ideas which are related or which "seem to go together" provide the basis for major headings or categories. Ideas that fall under any major heading can be easily reduced to any level of subordinate heading. Even if the user determines at a later time that an idea does not belong under a certain heading, there is no problem since any piece of text can easily be moved within the outline-- as many times as necessary. The program automatically reorganizes the Roman numerals, letters and numbers designated for specific headings. Outlining programs also enable users to limit what is viewed on the computer screen to only the major headings to facilitate an overview of the document, as well as to select single subordinate headings and view all information under it for a detailed analysis. This may be a useful option for those persons who become so focused on details that they can't see the big picture, or inversely, for those whose writing is excessively "skeletal" and lacking in detail.

Programs also exist (e.g., Inspiration[R]) that have graphic capabilities which can facilitate "brainstorming" by enabling the users to create a diagram of their ideas (semantic webs, "mind maps," cluster diagrams) prior to formulating an outline. The user types in a main or central idea that is displayed on the screen. Related ideas are then input, and appear in specified geometric shapes (e.g., circles, ovals, rectangles) surrounding the central idea. Ideas may be linked with the main idea (and each other) by lines. Ideas can easily be moved, rearranged and categorized. Detailed notes can also be attached to specific ideas and hidden from view. Ultimately, the graphic representation can automatically be converted to an outline. This non-linear, "free-form" graphic approach may be even more helpful to some students than simple text based outlining.

Outlining programs and graphic organizers usually require about one to three hours of practice before they can be used with any degree of proficiency. If an "add-on" outliner has to be purchased it is available for between approximately \$100 - \$400. Graphic organizers cost about \$90.

Abbreviation expanders. Abbreviation expansion is used in conjunction with word processing and allows users to create their own abbreviations for frequently used words, phrases or standard pieces of text, thus saving keystrokes, and ultimately the amount of time it takes to prepare written documents. This is an important consideration in light of the fact that some students with LDs may take longer to complete tasks than their non-disabled peers (Blalock & Johnson, 1987). For example, an LD student in a history class who has to frequently type out "industrial revolution" in completing written assignments, might create the abbreviation "ir."

In order to expand an abbreviation, the user simply types in the abbreviation (e.g., "ir"), presses the spacebar on the keyboard (or depending on the particular program, points and clicks), and the abbreviation is expanded (e.g., "industrial revolution"). Abbreviations are easily recorded by executing a few simple commands and may be saved from one writing session to another.

Abbreviation expansion is an integral part of some word processing programs and is also available as "memory resident add-on" programs (operating simultaneously with the word processing program). Add-on programs run about $100. Less than one hour of training is generally needed to learn to use abbreviation expansion.

Speech recognition. Speech recognition systems appropriate for use by postsecondary students with LDs, operate in conjunction with personal computers (and specific laptops) and consist of speech recognition hardware (internal board), software, head phones and a microphone. Speech recognition systems enable the user to operate the computer by speaking to it. This may be particularly helpful to those individuals with LDs whose oral language exceeds their written language abilities (Howell, 1956; King & Rental, 1981; Myklebust, 1973). When used in conjunction with word processors, sophisticated systems (e.g., DragonDictate™, Kurzweil Voice™) enable the user to dictate to the computer at forty to seventy words per minute (depending on the speed of the particular computer)-- converting oral language to written text. These systems automatically learn the phonetic characteristics of each person's voice while that person dictates to the system. The more the system is used, the better able it is to understand what the user is saying.

In order to operate the system, the user dictates through a microphone. At present, a calculated pause of approximately 1/10 second is required between words. The word the system "thinks" the person has spoken is placed on the screen. If the word is incorrect, the user can choose the correct word from a menu/list of similar sounding words which appear on the screen (this feature is not present in all systems, e.g., PowerSecretary™ for the Macintosh®). It should be noted that all keyboard editing and control commands (e.g., "delete word") can be done with the voice alone.

It takes approximately five to ten hours to train an LD student to work independently with the system. Training has two components: 1) instruction in the basic operational procedures and, 2) training the system to recognize the user's voice. The cost of DragonDictate™ and Kurzweil Voice™ is approximately $1,000 (not including the computer). The cost of PowerSecretary™ is about $2,300.

Speech synthesis/Screen reading. Several authors have suggested that speech synthesis be used as an assistive technology for postsecondary students with LDs (Brown, 1987; Norris & Graef, 1990). Speech synthesis refers to a synthetic or computerized voice output system usually consisting of an internal board or external hardware device. In conjunction with "screen reading" software, a speech synthesizer will read back text displayed on a computer screen so that the user can hear, as well as see what is displayed. Text can be read back a letter, word, line, sentence, paragraph or "screen" at a time. Screen reading programs are now available (e.g., SoundProof®) which are specifically designed for individuals with LDs, and which simultaneously (visually) highlight words as they are spoken. In most cases the speed, pitch, and tone of voice can be set to accommodate individual preferences. The voice quality of speech synthesizers varies considerably from more "human" to more "mechanical" sounding. In some instances, more mechanical sounding voices may actually be more intelligible. There are also synthesizers available that provide the user with the opportunity to select a number of different voices (e.g., male, female, young, old).

Speech synthesis/screen review technology, when combined with a word processing program, may be helpful to students with written language deficits. (The systems discussed here should be differentiated from speech synthesis systems which are tied to specific word processing programs). This is especially true for individuals who possess oral language skills that are superior to their written language abilities. For these persons, the ability to hear what they have written may enable them to catch errors in grammar, spelling, and punctuation that might otherwise go unrecognized. Having the auditory feedback may also help alert the LD user to problems regarding the coherence and semantic integrity of the document.

The cost of commercially available speech synthesizers varies greatly, ranging from approximately \$100 - \$2,000. However, a synthesizer of sufficiently high quality can be purchased from between \$700 - \$1,200. Screen reading programs appropriate for use with LD postsecondary students generally run between \$400 to \$600 (in some instances the synthesizer and screen reader are bundled together). The amount of time needed to learn screen reading programs also varies from product to product. However, most LD students should be able to operate the program adequately within one hour.

Word prediction. Word prediction software supports word processing programs by "predicting" the word a user is entering into the computer. Predictions are based upon syntax and spelling, as well as, frequency, redundancy and recency factors of words. Some programs also "learn" the user's word preferences. Typically, word prediction programs operate in the following manner. As the first letter of a word is typed, the program offers a list of words beginning with that letter. If the desired word appears in the list, the user can then choose the word (by pressing a corresponding number, or pointing and clicking) and the desired word will automatically be inserted into the sentence. If the desired word is not displayed, the user enters the second letter of the word and a new list appears with words beginning with those two letters. The user may continue this process until the desired word is offered in the list. If the word is not included in the programs database, it may be added for future use. After a word is chosen, the "next" word in the sentence is predicted, even before the first letter is typed. Again, if the desired word is not present, then the user continues to enter the letters until the word appears.

Word prediction may be helpful to postsecondary students with LDs for several reasons. First, since the program minimizes the number of keystrokes it takes to enter a word, students with poor keyboarding skills may find these programs easier and faster to use than standard word processors. Secondly, the program may act as a compensatory spelling aid, as it automatically spells the word out, and the user only needs to recognize the word within the list. Additionally, as these programs utilize "grammatical rules" to predict words, students with syntactical deficits may find the programs helpful. Finally, students who have "word finding" difficulties or "grope" for words, may discover that the word list acts as a prompt, cuing them to the appropriate word. It is important to realize that in some instances word prediction programs may actually interfere with the writing process (Cutler, 1991). The word list may be distracting, and having to stop and choose words may slow some students down, especially students who have significant difficulty in word recognition or who are proficient typists.

Word prediction programs are available as add-on programs that work in conjunction with standard word processors, and also as integrated word prediction/word processing software packages. Most word prediction programs require no more than an hour to learn and cost about $300.

Reading

Speech synthesis. The benefits of speech synthesis systems are not limited solely to use with word processors. They may also be used to review materials written by others, including software tutorials, help systems, letters, reports and on-line databases and information banks/systems. These systems will read essentially anything on a computer screen, providing it is DOS-based. Some organizations including Recordings for the Blind and the American Printing House for the Blind are now producing "books on disk" which make it possible for persons with LDs to listen to text by means of a speech synthesis system. Persons with LDs are eligible to receive services from these organizations. There are also several on-line electronic-text library collections available through the Internet, which house large collections of classic works that have the potential to be read aloud by means of a speech synthesis/screen review system.

OCR/Speech synthesis systems. An OCR system might be thought of as a "reading machine." OCR systems provide a means of directly imputing text/printed material (e.g., a page in a book, a letter) into a computer. Text is input by using a full-page flatbed scanner in which a page of text is placed face down on the device (much like a copy machine), or a hand-held scanner which the user moves across a page of text (or down depending on the particular system), or a full page scanner. "Book-edge" (designed for bound text) scanners and automatic document feeders are also available for several systems. Once the text has been scanned into the computer, it can then be read back to the user by means of a speech synthesis/screen reading system. This technology may be particularly helpful to those LD individuals who exhibit no difficulty comprehending spoken language (Gough & Tunmer, 1986), yet have problems understanding language in the written form (Hughes & Smith, 1990).

OCR systems are of two basic types-- "stand alone" or PC-based. Stand alone (or "self-contained") systems have all components built into one device, including the scanner, OCR software/hardware, and the speech synthesizer. Some stand alone systems are portable, others are desktop units. The PC-based systems consist of a number of components which are hooked up to a PC. These components consist of a full-page (desktop) or hand-held scanner, an OCR board and/or software, and a speech synthesizer. Several companies have designed systems with the LD individual in mind (i.e., Xerox/Kurzweil's BookWise, Arkenstone's Open Book) which simultaneously highlight words as they are spoken back by the system. The cost of OCR systems also varies widely, ranging in price from \$3,000 - \$5,000 (excluding the computer on the PC-based systems). It is important to keep in mind that the speed and accuracy of many of the low end systems may be inadequate for the postsecondary student with LDs. Several systems can be used quite effectively after only a couple of hours of instruction.

Variable speech control tape recorders. Portable audio-cassette recorders have been recommended by a number of authorities as a compensatory aid for postsecondary students with LDs (Mangrum & Strichart, 1988; Scheiber & Talpers, 1985). Among the possibilities is the use of tape recorders as playback units for listening to books on audiotape, which may help students with reading difficulties circumvent their disability by listening to prerecorded text (books, journals, newspapers). Prerecorded text is available from a number of sources, including The Library of Congress and Recordings for the Blind, and several private companies. Although tape recorders may be helpful to some students, they may present problems for those individuals with LDs who have difficulty processing auditory information at standard playback rates (McCroskey & Thompson, 1973). This problem can be alleviated by the use of variable speech control (VSC) tape recorders which, unlike standard/conventional tape recorders (or units that simply have different record/playback speeds), enable the user to play back audio-taped material (e.g., books-on-tape) slower or faster than the rate at which it was initially recorded, without the loss of intelligibility. Intelligible speech at varying rates is achieved by adjusting speed and pitch control levers. These devices enable the user to slow down prerecorded text by 25% of the standard rate without the loss of intelligibility. VSC tape recorders range from approximately \$100 - \$200 and usually require no more than thirty minutes of training.

Organization/Memory

Personal data managers. Postsecondary students with LDs often have difficulty remembering, organizing and managing personal information (Mangrum & Strichart, 1988; Vogel, 1987). It may be a question of scheduling appointments, prioritizing activities, remembering important dates/deadlines, or recording/accessing names, addresses and phone numbers. The use of personal data managers can compensate for difficulties in this area. Personal data managers are available as software programs as well as self-contained hand-held units and allow the user to easily store and retrieve vast amounts of personal information. Data is input and retrieved via a keyboard/keypad and is displayed on a computer monitor or LCD display. A newly released hand-held data manager (Voice Organizer™) allows the user to enter and retrieve data by speaking into the device. Stored data is spoken back in the user's own voice. Data managers have numerous capabilities and a diverse combination of functions. Typical features include monthly calendars, daily schedules/planners/appointments, clocks/alarms, memo files, "to do lists," name/address books, telephone directories (some with electronic dialers), and bankbooks/check registers/money managers. These products range on the average from about \$20 - \$150 and only require from fifteen minutes to two hours to learn.

Free-form databases. Like personal data managers, free-form databases may also be valuable to individuals with organizational and/or memory problems. These software programs work with computers and might be thought of as "computerized Post-It™" note systems. Like abbreviation expanders, they are memory resident and can be activated while in a word processor or other programs by simply pressing a "hot key." Users can create their own notes of any length, on any subject, in much the same way people use Post-It™ notes, a notepad, or scraps of paper to jot down important information. Unlike a manual system, free-form databases enable the user to electronically store the notes in the computer's memory, rather than on tiny pieces of paper that are easily misplaced.

Perhaps more important than how the information is stored, is how it is retrieved. A note can be retrieved by typing in any piece or fragment of information contained in the note. For example the note: *Carl Stevens, Advanced Electronics, Inc., 835 West Arden, Northridge, CA 91330, (818) 306-1954* could be brought up on the computer's screen by inputting any of the following information, including (but not limited to): "Carl," "Advanced," "West," "North," and "818." The basic functions of a free-form data base are relatively simple to learn and can be mastered in about two hours. Programs can be purchased for about $100.

Listening Aids

Personal FM listening systems. Research has indicated that some adults with LDs have difficulty focusing auditorially on a speaker (Hasbrouck, 1980). Such difficulties may lead to misunderstanding or missing information presented during a classroom lecture or meeting. One device which may help LD students focus on a speaker is a personal FM listening system. These technological aids consist of two basic components, a wireless transmitter with a microphone and a receiver with a headset or earphone. For situations in which there is only one speaker (e.g., a professor in a classroom), the speaker "wears" the transmitter unit (about 2" x 3"), while the user wears the receiver unit (also about 2" x 3"). The transmitter or receiver is easily clipped to a belt or shirt pocket. The microphone is only about 1 1/2" long and is easily clipped to clothing (e.g., tie). When there are multiple speakers (e.g., a meeting) an omni directional microphone enclosed in a small stand alone unit is placed in the center of the conversational interaction. Essentially, these systems carry the speaker's voice directly from the "speaker's mouth" to the "listener's ear" helping to make the speaker's voice more salient. Volume is easily controlled by a dial on the receiver. These devices run on "AA" size rechargeable or disposable batteries. The cost of such devices range from $300 - $600. It takes only a matter of minutes for an LD student to learn to use these systems.

Tape recorders. In addition to helping compensate for reading disabilities, tape recorders may also be useful to the student with listening difficulties (as well as memory problems). Tape recorders can be utilized to record classroom lectures, as either an alternative or supplement to taking notes. This may be beneficial for LD students who have listening difficulties (either because of difficulty processing oral language or attentional disorders), since they can review lectures at a later date, listening to tapes as many times as necessary to comprehend the material. The ability to commit a lecture to a permanent record may also aid LD students with other types of difficulties including those who find it troubling to take notes and listen simultaneously, students with fine-motor dysfunctions, and those with auditory memory problems. VSC tape recorders may be particularly helpful for reviewing taped material, since they enable the user to increase the speech rate (generally up to 100%), in order to reduce the amount of time it takes to "re-listen," or as previously discussed, reduce speech rates to more comprehensible levels.

Math

Talking calculators. A talking calculator is simply a calculator with a speech synthesizer. When number, symbol or operation keys are pressed, they are "vocalized/spoken" by a built-in speech synthesizer. In this way, the user receives simultaneous auditory feedback in order to check the accuracy of visual-motor operations. Once a calculation has been made, the number can be read back via the synthesizer. This feature enables the user to double-check the answers being transferred from calculator to paper.

It is important to note that the speed at which calculations are performed may be problematic, since it takes longer to have operations spoken than displayed. Secondly, some students may experience "stimulus overload," having to contend with both visual and auditory feedback. As with all technologies, individual profiles and preferences will have to be considered. Talking calculators take only about fifteen minutes to learn. Most talking calculators can be purchased for between $20 to $75. Bryant et al. (1993) stresses that postsecondary students with LD's are likely to need scientific programmable calculators. Scientific programmable units with speech capabilities may cost as much as $650.

Research on the Effectiveness of Assistive Technology for Postsecondary Students with LDs

There is a paucity of formal research regarding the effectiveness of assistive technology for postsecondary students with LDs. Indications of effectivenss have been derived primarily from anecdotal reports and case studies (e.g., Brown, 1987; Bryant, et al.; Collins, 1990; Collins & Price, 1986; Cutler, 1990, 1991; Norris & Graef, 1990; Primus, 1990; Raskind & Scott, 1993). The limited research which has been conducted in this area is briefly reviewed below. Particular attention will be given to the authors' federally funded research at CSUN.

Collins (1990) conducted a three-year study on the impact of word processing on the writing performance of college students with LDs in a required first year writing course. Results suggested that the use of word processors helped students with LDs complete a first year writing course at rates similar to non-disabled peers, achieve grades at least comparable to non-disabled peers, and improve writing fluency. According to the researcher, the use of word processors also lead to a significant reduction in writing apprehension among students with LDs. Similarly, Primus (1990) studied the impact of word processing on grades and grade point averages of university students with LDs. Results of this study indicated that freshman English grades, and semester and cumulative grade point averages were higher for LD students using word processors as compared to LD non-computer users while they were taking freshman English. However, the researcher emphasized that the trend toward higher academic performance was not sustained throughout participants' academic careers.

McNaughton, Hughes & Clark (1993) investigated the effect of five writing conditions on the spelling performance of college students with LDs: handwriting, handwriting with a conventional print dictionary, handwriting with a hand-held spell checker, word processing, and word processing with an integrated spell checker. Results indicated that the word processor with an integrated spell checker provided a statistically significant advantage over the other four conditions in the detection of spelling errors. The word processor with an integrated spell checker also showed a statistically significant advantage over handwriting and word processing (but not over the other conditions) in "correction activities." The authors also report that the word processor with spell checker also demonstrated a significant advantage over handwriting and word processing, but not over handwriting in combination with a spell checker or conventional dictionary.

One of the most comprehensive studies on assistive technology for postsecondary students with LDs was conducted by the Center on Disability at CSUN under a three-year grant from the United States Department of Education, Fund for the Improvement of Postsecondary Education

(Grant #P 116B10821). In the first year of the project, the compensatory effectiveness of three technologies were investigated: 1) OCR/speech synthesis as a compensatory reading strategy; 2) speech synthesis/screen review as a compensatory proofreading strategy; and 3) speech recognition as a compensatory writing strategy. In years two and three of the project, changes in academic outcomes, behaviors, and attitudes as a result of assistive technology use were studied. The cost effectiveness of these technologies was also investigated in the final year of the project. A brief description and the results of each phase of the project appear below.[2]

During the first year of the study the immediate compensatory effectiveness of the technologies was investigated. OCR in conjunction with speech synthesis was evaluated as to its effectiveness in compensating for difficulties with reading comprehension. Thirty-seven postsecondary students with LDs[3] in the area of reading were trained on the technologies and given the Formal Reading Inventory (Wiederholt, 1986) under three conditions: (1) reading the test silently without assistance; (2) having the test read aloud by a human reader; and (3) converting (scanning) the test into a computer document using an OCR system, then having it read aloud using a speech synthesis/screen review system. No differences were found in the means of standard scores across the three conditions. This was due to the fact that the technologies helped some readers while interfering with the performance of others. There was, however, a significant correlation ($p=.001$) between silent reading scores and scores obtained using the assistive technology such that the greater the disability in silent reading, the more the

[2] The studies on speech synthesis and speech recognition are in press, Raskind & Higgins; Higgins & Raskind (respectively), Learning Disability Quarterly.

[3] Students were selected from the CSUN Learning Disability Program and identified as "LD" in accord with the criteria of the California State University Chancellor's Office.

technology assisted the student to compensate for the difficulty. A similar but weaker correlation was found when the test was read aloud by a human reader ($p > .01$). These findings taken together suggest that the auditory presentation of text (whether by human voice or by computer) assisted less proficient readers with the decoding process (thus elevating their scores), but interfered with the more efficient silent reading processes for the proficient readers.

Speech synthesis/screen review was also assessed as to its effectiveness in increasing students' efficiency at proofreading written compositions. Thirty-four students with LDs in the area of written language composed the first draft of an essay approximately 500 words in length. The essay was divided into three equal parts, each of which was proofread under the following conditions: 1) without assistance; 2) having the essay section read aloud by a human reader; and 3) having the essay section read by the speech synthesis/screen review system. Students found significantly more errors overall using speech synthesis/screen review than when proofreading without assistance or when proofreading while a human reader read the essay section aloud. Additionally, speech synthesis/screen review proved superior at assisting students in finding particular types of errors in comparison to proofreading without assistance.[4] Typographical errors as well as errors in capitalization, spelling and usage were found at a significantly higher rate using the technology. Having the essay section read aloud by a human reader proved significantly superior to proofreading without assistance for two types of errors, spelling and mechanical grammar errors. Finally, when comparing human readers to speech synthesis/screen review, human readers were superior to the technology at a significant level for one category--mechanical grammar errors (Raskind & Higgins, in press).

[4] Error categories included capitalization, punctuation, spelling, usage, grammar-mechanical, grammar-global, typographical, content/organization, and literary style.

Finally, speech recognition technology was evaluated as to its compensatory effectiveness at improving written composition skills. Twenty-nine postsecondary students with LDs in the area of written language were trained on the speech recognition system and asked to write three essays under the following conditions: 1) without assistance (students could either handwrite or use a word processor to generate the "no assistance" essay); 2) dictating the essay to a human transcriber; and 3) using a speech recognition system. The essays were designed to emulate the Upper Division Written Proficiency Examination (WPE), a timed, holistically scored essay required by the University in order to graduate. Significantly more students received a higher holistic score on the essay written using speech recognition than when writing without assistance ($p > .05$). A post-hoc analysis of the essays indicated that students used significantly more "long words" (words of seven or more letters) when using the equipment, and further that the use of words with seven or more letters was positively correlated with better holistic scores at a significant level ($p > .0001$).

In years two and three of the project, changes in academic outcomes, behaviors, and attitudes as a result of assistive technology use were studied. These results are reported briefly below. It is important to emphasize that this portion of the study was more descriptive than experimental. Data was derived from interviews, questionnaires and self-reports, supplemented where possible by computer log-on records, official reports and databases which documented the use of services. It is acknowledged that many of the reported changes may have been due to factors other than those under investigation. It is also possible that the sample "self-selected," with subjects of particular "psychological constitutions" or personality characteristics being drawn to participate in the study.

The 140 students who received training on the technology over the three-year period showed several positive academic outcomes: a) participants significantly increased ($p > .05$) their GPAs for courses with heavy reading and/or composition requirements while a matched control group did not (although these gains were not sufficient to increase overall GPAs so that they reached significance); b) the University attrition rate for the 140 subjects was only 1.4% over the three-year period, compared to 34% for a matched group of students with LDs who did not participate in training (and 48% for non-disabled students over four years (CSU Stateline, 1994); c) although participants in the study received similar numbers of withdrawals and incompletes as the matched group, they showed significantly higher rates of repeating the courses until a satisfactory grade was obtained; and d) participants' WPE first-time passage rates were 95%, compared to 50% passage rates for both the matched group and for the population of LD students prior to the study, and 75% overall passage rate for the general CSUN population.

Examination of log-on programs and responses to pre- and post-training questionnaires revealed several changes in academic behaviors among the participants in the study. These changes included: a) a 78% increase in hours of use of assistive technology in general, which was accounted for primarily by greater use of word processing; b) an increase among 75% of the participants in extending the use of word processors for academic purposes other than composition, such as note taking, organizing course content, outlining reading material, and time management; c) an increase among 90% of the participants in expanding the use of computers into non-academic settings (e.g., employment, recreational/social); d) increases in the use of assistive technologies not utilized in the study (e.g., VSC tape recorders,books on tape); and e) an eight-fold increase in the use of the three technologies under study by persons trained in the study.

Examination of databases documenting use of services through the Computer Access Lab and questionnaire responses also indicated that participation in the study and/or use of assistive technology had been accompanied by changes in the use of compensatory strategies other than technological strategies, including: a) an initial tendency to increase the use of services offered by the CSUN Learning Disability Program and other campus services by newly-identified students, followed by a decrease in the use of services by previously-identified students, over the three year period; b) an overall increase in independence suggested by less frequent use of family members, friends, classmates and fellow employees to assist students in compensating for their disabilities; and c) changed roles in study groups or with informal classmate study relationships from "helpee" to "helper."

Previous research on adults with LDs (Gerber, Ginsberg & Reiff, 1992; Spekman, Goldberg & Herman, 1992) has indicated that successful adults tend to accept rather than deny their disability; to be users of technology; to use a variety of compensatory strategies in response to situational variables; to be self-advocates in terms of their disabilities; and to be active members of groups that advocate for persons with LDs. Questionnaire responses indicated that attitudinal and affective changes had taken place as a result of training and/or participation in the study in the direction of the above cluster of attributes associated with successful adults: a) two-thirds of the respondents reported having learned more about their strengths and weaknesses and about LDs in general as a result of participation and training; b) eighty percent of the students related they felt better about themselves academically since discovering more about their disabilities through participation; c) nearly half the respondents reported, literally, that "the computer has changed my life [for the better]," allowing them to accomplish tasks they had previously been unable to do; d) nearly a third reported that they "couldn't have made it through," without the help of training on assistive technology; e) one-third of the students reported alteration of their career goals to include working with other students with LDs or related difficulties as a result of participation in the study.

Cost effectiveness was evaluated for the technologies in year-three of the study. The analysis was prepared with regard to the costs which would be incurred by the service delivery point for assistive technology at CSUN, which is a well-established office of disabled student services with a well-trained technical support staff, a history of attracting many student volunteers and adequate funding for several student assistants to provide a variety of services for students with disabilities, including LDs. Elements included in the analysis were the initial cost of equipment, equipment repair/maintenance, consumable supplies, and initial training and supervisory/monitoring costs once students were trained (given current staffing and salary schedules). The estimate was then adjusted for projected increases in use of assistive technology services and other support services using data gathered from the questionnaire given to students from the study and on log-on times taken from the Computer Access Lab. The estimate was then compared to the cost of providing equivalent non-technological services such as transcribers, readers, tutors, counselors and notetakers, given current staffing and salary schedules. Two estimates were computed: 1) a minimal "bottom-line" cost estimate which covered initial equipment purchases initial training costs and post-training monitoring needs for the projected number of students likely to request services, given current turnover rates; and 2) a maximal estimate which, in addition to the costs listed under 1), included some student outreach efforts to previously identified LD students, needs assessment activities of the current population of students with LDs and the provision of specialized training based on the needs assessment.[5] It was determined that the net savings for the ODSS for the minimal services was $320 per student per semester and $260 for the maximal services. The amount was then adjusted for projected increases in use of other services within ODSS and to other campus service providers, for a net benefit of approximately $310 for the minimal service provision and $234 for the maximal service provision, per student per semester.

It is important to stress that the evaluation of cost effectiveness of any assistive technology is highly dependent on the context in which the analysis is conducted. Therefore, readers are cautioned not to generalize the results reported herein to other settings (e.g., employment, rehabilitation, etc.), or even other university/college settings, since even "comparable contexts" may vary markedly in regard to goals, purposes and policy regarding the delivery of assistive technology, other support services to persons with LDs, the location within the postsecondary institution of the assistive technology delivery point (e.g., office of disabled students services vs. centralized computing center), and budgetary policy, (e.g., soft vs. hard funding for technological training and/or equipment purchases).

Summary and Recommendations

The provision of assistive technology to postsecondary students with LDs has had a relatively short history, and should be considered to be in a stage of "infancy." Although assistive technology LD support services are growing, considerable investigation, exploration

[5] The maximal amount was based on actual outreach, needs assessment and service provision costs which were incurred during years two and three of the study. The needs assessment conducted in year two determined that two areas of need were salient to participants in the study--passage of the WPE and instruction/guidance on how to write a term paper. Two "mini-courses" were developed entitled, "Writing a Term Paper Using Technology," and "Passing the WPE Using Technology." Flyers were sent out to all students with learning disabilities each semester. Sixty students responded and subsequently participated in the mini-courses.

and experience is still needed to determine the most appropriate service delivery models, specific services, and technologies necessary to meet the needs of individual institutions, LD support service programs, and students with LDs. Additionally, while numerous technologies are now available to help postsecondary students with LDs compensate for a variety of difficulties, there is a paucity of research to support their efficacy. Only a limited number of studies have been conducted on a narrow range of technologies.

Although research in the area of assistive technology and postsecondary students with LDs is quite limited, collective results are suggestive of a number of general conclusions including: a) select assistive technologies have been found to be effective for some students in compensating for specific deficits in such areas as writing and reading; b) a specific technology which may be beneficial for one LD individual could be counterproductive for another; c) it is unclear whether the use of assistive technology leads to improved academic outcomes (e.g., improved overall GPA, retention); d) "low tech" or even "no tech" solutions may be more effective than a "high tech" assistive technology; e) specific types of technology (e.g., speech synthesis) may be helpful in compensating for one area of difficulty (e.g., proofreading), but not necessarily another (e.g., reading); f) the fact an assistive technology has compensatory value, does not guarantee that it will be cost/time effective; g) a technology may be more effective than alternative strategies in helping a specific area of skill deficit (e.g., speech synthesis in catching usage errors) but not in others, (e.g., locating grammar mechanical errors); and h) the use of some assistive technologies appear to have a positive behavioral and/or psychological/attitudinal effect on specific students. The use of assistive technology as a means to help postsecondary students with LDs compensate for their difficulties and enhance academic success appears promising. However, in order to ensure that the full benefits of assistive technology are achieved, concerted efforts will have to be made to continue to research: a) the compensatory effectiveness of select technologies on specific difficulties; b) academic outcomes; c) possible behavioral and/or psychological benefits (e.g., changes in levels of independence, self-esteem); d) the long-term effects of assistive technology use; and e) cost effectiveness. In addition, attempts will have to be made to: 1) identify the most effective service delivery models and practices; 2) keep abreast of emerging technologies; 3) promote awareness of assistive technology to faculty, support personnel and administration; and 4) work cooperatively with technology manufacturers to identify and develop/modify appropriate technologies specifically for individuals with LDs. It is only through such efforts that the full potential of assistive technology for helping postsecondary students with LDs can be realized.

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APPENDIX C

Questionnaire/Interview Schedule on

Use of Assistive Technology,

Use of Campus Services and

Formal and Informal Compensatory Strategies

QUESTIONNAIRE

Use of Services\Independence

A. Office of Disabled Student Services

How often do you use the following services from Disabled Student Services?

Transcriber	___	per	____	(day, week, month, semester)
Reader	___	per	____	
Notetaker	___	per	____	
Test proctor	___	per	____	
Tutor	___	per	____	
Proof reader	___	per	____	
Assessment Testing	___	per	____	
Testing Accommodation				
extra time	___	per	____	
reader	___	per	____	
transcriber	___	per	____	
Counselling				
Career	___	per	____	
Personal	___	per	____	
Group	___	per	____	
Acad. Advisement	___	per	____	
Computer Equipment				
Word processing	___	per	____	
Soundproof	___	per	____	
OCR	___	per	____	
Dragon Dictate	___	per	____	
Spell Check	___	per	____	
Grammar Check	___	per	____	
Outline Program	___	per	____	
Other__________	___	per	____	
Other Equipment				
Books on tape	___	per	____	
Tape recorder	___	per	____	
Other	___	per	____	

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B. **Other Campus Facilities**

Computer Labs ___ per ___ Which ones? ________

Lrn.Resource Ctr.
Study Skills Seminar Topic? ____________
Tutor: Math ___ per ___
English ___ per ___
Subject ___ per ___ Which subjects? ________

Remedial Courses
Math 094 ___
Eng. 097 ___
Eng. 098 ___

Counselling Center ___ per ___ Type of counselling ______
Career Center ___ per ___ Type of service ________
Educational Equity ___ per ___ Type of service ________

C. **Off Campus Services?**

Counselling ___ per ___ Type of counselling ______
Tutors ___ per ___ Subject ______________
Other ___ per ___ ____________________

D. **Informal Help?**

Family:
My ____________ helps me __________, ___ times per ___.
(mom, husband?) (proofread?)

My ____________ helps me __________, ___ times per ___.

My ____________ helps me __________, ___ times per ___.

Friends: ____________ helps me __________, ___ times per ___.

____________ helps me __________, ___ times per ___.

____________ helps me __________, ___ times per ___.

Classmates:
____________ helps me __________, ___ times per ___.

____________ helps me __________, ___ times per ___.

____________ helps me __________, ___ times per ___.

E. **Work-related Accommodation/Assistance**

Do you currrently have a job? _____ Hours per week you work?___

Have you ever had a job?___

Description of duties ____

____

What kinds of compensations did you have to make in order to accommodate your disability? (special assignments, help from co-workers, extensions of time for certain tasks, etc.)

____

____

What are your career goals?_______________________________________

What kinds of compensations or accommodations for your difficulties do you foresee making in your career?

____

Study Habits

Class Participation

Do you take notes in class?
During lectures? ___
During lab sessions? ___
During movies and other presentations? ___

Use a tape recorder for any of your classes?

How frequently do you participate orally in class? ___ %

How frequently do you ask questions?
- ___ never
- ___ when you don't understand something
- ___ when a question occurs to you during a lecture or discussion

When you are having trouble understanding something in a course, do you seek out the TA or instructor?
- ___ every time I am confused
- ___ after I have struggled with it for a long time
- ___ only if I have failed a test or important assignment
- ___ never

How often do you miss class? ___ time(s) a ___________.
So if you have three classes, you miss ______ times a ______?

Do you get notes and assignments from someone when you return?

Assignments

How often do you miss turning in assignments or homework? ____ time(s) a __________.

How often do you turn in assignments late? ____ time(s) a ________.

How often do you get help from classmates, friends or family in completing your assignments?

What kind of help do they provide?

Do you type, write out or use a computer to do your assignments?

If you had a 10 page paper due on say May 1st, when would you begin working on it?

Study

I study about ____ hours a week for each class.

I do ____% of the assigned reading in each class.

I usually do the following to prepare for a test:

- ___ review class notes
- ___ review reading material
- ___ memorize important points
- ___ study with a group or with classmates
- ___ plan or outline answers to possible essay questions
- ___ "rehearse" oral presentations or exams
- ___ outline important information
- ___ review old versions of exams
- ___ other

Prior Computer Experience

Typing: ___ I hunt and peck.

___ I touch type about ___ words per minute.

I have used a computer to do the following:

___ word processing
___ games
___ spreadsheets
___ calendar/organizer
___ checkbook and budgeting
___ programming
___ billing
___ data base
___ desktop publishing
___ graphics
___ engineering
___ communication
___ on my job (To do what?________________________________)
___ other____
____

I currently use a computer about ___ hours a week to do the following:

____

____

____

Additional Post-Session Interview Questions

Tests:

Have you taken the WPE yet? How did you do?

Did you take any other qualifying tests such as the CBEST, LSAT, GRE?
How did you do?

Academic Standing

How are your grades today? Are you satisfied with them?
Have they improved, gotten worse since the study began?

Have you been on academic probation since the study began?
Are you satisfied with your progress toward a degree?

When do you plan to graduate?
What do you have left to do to (graduate)?

Use of Computer Equipment

Have you increased your use of computers since the study began?

Of the CAL?

Of other ODSS services?

Future Plans

What are your academic plans for the future? (Grad school?)

Do you plan to get more training on computers in the future?

Have your plans for the future been modified as a result of use of the computer?

Feelings

How do you feel about your success as a student?

Have your attitudes toward school changed as a result of the study in any way?

Has the ODSS and/or the CAL helped you to achieve your academic and/or personal goals?

Applications Outside University

Do you use the computer for tasks outside your coursework, for obtaining employment, such things as as making out resumes and job applications, etc.?

Has the computer entered your social life? For example, some people use it to organize appointments and special dates; some participate in electronic bulletin boards and actually get to know people that way; technology becomes a topic of conversation in many social settings. Have any of these things occurred in your experience, or other uses which might be termed "social" uses of the computer?

How about at home? Do you use a computer to do budgeting, scheduling, work with other family members perhaps?

Do you use the computer for personal purposes? For example, is playing computer games one of your hobbies, or do you have a hobby that involves using the computer? Or, perhaps you keep a diary on it. Any personal uses?

APPENDIX D

Course Outlines for Mini-courses in

Utilizing Assistive Technology to Enhance the Written Composition Skills

of Postsecondary Students with Learning Disabilities

THE PROCESS
OF
WRITING A TERM PAPER
USING TECHNOLOGY

Choosing a Topic

- Read instructions
- Brainstorming *
- Narrowing/Expanding *
- Reread instructions

Organizing the Paper

- How will I organize?
  - Outline *
  - Mind-mapping *
  - Other
- What will I organize?
  - Reread question:
    - compare/contrast
    - describe/explain
    - analyze/synthesize
    - evaluate

- Making the Outline (Top-down outlining) *
  - Main points (section headings) *
    - Subtopics (paragraphs)
      - Points (sentences)
  - Choose specific examples
  - Generalize to a "higher" level

Planned Research

- What do I know?
- What do I need to know?

- Making a list
- Searching for sources *
- Rules of citation
- Bibliography notes *

First Draft

How will I write?
- handwritten
- word processed *
- dictated (transcribed?) *
- voice recognition *

What will I write? (the outline)

Get ready to write:
- Write from the outline (Find the outline.)
- Turn off the "editor"
- No rereading

Write:
- Write a section at a time *
- Let it flow (Don't stop for anything.)
- Be Creative (Be dramatic. Use your native English-speaking intuition to decide what comes next, what kind of sentence to use, what "sounds" good.)
- Be Smart (Use your biggest and best words.) *
- Be Powerful (Convince, shock, take a stand, have an impact.)

Rewrite

- Evaluate the CONTENT *
- Reorganize *
- Reword *
- Disciplined Deletion (limbo) *

Proofread

Nine categories of errors

Capitalization, Punctuation, Spelling, Usage, Grammar-Mechanical, Grammar-Global, Typographical, Content/Organization, Style

Three Readings

Whole Paper *
- Content/Organization
- Grammar-Global
- Style

Sentence by Sentence *

Grammar-Mechanical
Usage
Capitalization
Punctuation

Word by Word *

Spelling
Capitalization
Punctuation
Usage
Typographical

Consult

Instructing the Consultant (People nitpick)

Read whole paper, sentence by sentence, word by word
To rewrite or reproof
For content only, etc.

Get Tough (Combat discouragement. Live to write again!)

Imagine yourself as Kathryn Hepburn, or Spencer Tracy. You are wise, but you are tough. This stuff just rolls right off your back.

Keep Quiet (Yes...But)

Like Hepburn or Tracy, you always have a snappy comeback, but right now you are going to keep it to yourself while you listen to what this guy or gal has to say.

If you falter (start defending yourself, get your feelings hurt) concentrate on evaluating your consultant. How well is he/she doing at following your instructions? Judge your judge as he/she is judging you. Decide later which comments you will act on.

Take Notes (We forget what stings) *

Imagine yourself as the stenographer for the author. You are only passing on the comments. Your job is merely to get it all down.

Decide which comments you'll incorporate. *

Final Product

One Last Look *
Letting it Go

PASSING THE UPPER DIVISION WRITTEN PROFICIENCY EXAM
Using Technology

Understanding the Question 2 minutes

REREAD the question

Identify KEY ACTION WORDS

CLASSIFY it
- Compare and contrast
- Describe or Explain
- Analyse and Synthesize
- Evaluate (Analyse, Synthesize, Evaluate)
- Argue and Support
- Combination
- Other

PLAN to write 500 words (3 double-spaced, typed pages)

Picking A Topic 3 minutes

Have a topic?
- Does it fit the classification above?
- Can you write 500 words about it?

Brainstorming

Narrowing
- Focus on one box in your mind map?
- Focus on a part of the question?
- Focus on a part of the population or time period?

List what you can cut if you run out of time.

Elaborating

- Analyse
- Synthesize
- Compare
- Contrast
- Describe with the senses
- Explain the steps
- Evaluate
- Argue For or Against
- Add examples

Generalizing

- Higher levels of your social group:
  - me-family-neighborhood-community-state-country-international-humankind
  - individual-group-culture-intercultural
- Higher level of a process:
  - reflex-automatic behavior-learned behavior-intentional behavior
- Higher level of comparison:
  - compare effect on business to effect on art
- Higher level of knowledge:
  - recitation-analysis-synthesis-evaluation

Selecting Good Examples 2 minutes

Evidence

- Does it support or explain your argument logically?
- What type of evidence is it?
  - Direct/Indirect (circumstantial or inferential)
  - Testimonial/Real/Documentary
  - What is the cause/effect relationship? (time)
- What is the outcome? (Does it fit?)
- How far can you generalize it to other situations?

Metaphors (simile, part/whole)

- What parts are identical to your situation?
- What parts are different?
- How close is the connection?

Organizing the Essay 5 minutes

How will I organize?
- Outline
- Mind-mapping
- Other

Making the Outline
1. Top-Down Outlining
   Main points (section headings)
      Subtopics (paragraphs)
         Points (sentences)
2. Be specific with examples
3. Generalize to a "higher level"

Writing the Essay 43 minutes

*

How will I write:
- handwritten
- word processed
- dictated (transcribed?)
- voice recognition

Get ready to write:
- Write from the outline
- Turn off the editor
- No rereading

Write:
- Write a section at a time
- Let it flow (Don't stop for anything)
- Be Creative (Be dramatic. Use your native English-speaking intuition to decide what comes next, what kind of sentence to use, what "sounds" good.)
- Be Smart (Use your biggest and best words.)
- Be Powerful (Convince, shock, take a stand, have an impact.)

Proofreading the Exam 5 minutes *

Nine categories of errors

Capitalization, Punctuation, Spelling, Usage, Grammar-Mechanical, Grammar-Global, Typographical, Content/Organization, Style

Three Types of Readings

Whole Paper

Content/Organization
* Grammar-Global
* Style

Sentence by Sentence
* Grammar-Mechanical
* Usage

Capitalization

Word by Word
* Spelling

Capitalization

Punctuation
* Usage

Typographical

APPENDIX E

Sample Lesson Plans for Training on a Speech Recognition System

As an Assistive Technology for Postsecondary Students with Learning Disabilities

Lesson One

1. Overview

   a. Dictate a word, it appears on the screen

      Demonstrate a sentence

   b. Training the Dragon

      i. <u>Command Words v. Vocabulary Words</u> English / Yours

      ii. <u>Special Drills v. Practice Sessions</u>

   c. Importance of Saving Voice Files

      <u>Voice File v. Text File</u>

      Demonstrate saving a file

   d. Goal- 5:1 error ratio minimum
      7:1 better
      10:1 ideal
      Don't exceed 12 hours training
      Notify Eleanor you're ready for testing

2. Logging On/Off

   Demonstrate
   Practice

3. Training the command words

   Demonstrate
   Practice

4. Correcting Errors

   HAVE DICTIONARY HANDY

   <u>All Voice</u> (alpha/bravo)

   <u>With Keys</u>

   Demonstrate two methods
   Practice two methods

5. Train command words

Lesson Two

1. Logging On/Off

   Demonstrate

2. Complete command training

3. Voice Training

   <u>Introduce Materials Box</u>
   Speed-up Drills
   Snippets to Read to the Dragon
   Essay Motivations
   Class Assignments
   Materials of your choice

4. Correcting Errors

   a. <u>All Voice</u> — <u>With Keys</u>

      i. "Begin spell mode" — i. Type letters

      ii. "alpha, bravo.."

      iii. "OK" "Choose___"

   b. Say next word.

   Demonstrate both methods.

   Allow students to try each method. Offer a 5 minute correction practice session. Offer something from the materials box if necessary.

5. Demonstrate "scratch that" and "oops" and "fix" menu.

   Explain that "scratch that" does not correct the voice profile while "oops" does.

   "Oops" goes back only six utterances.

   Demonstrate "fix" key (-).

   Allow students to practice "scratch that", "oops", and "fix" key.

(Rest of the lesson to be spent in a voice training/correcting session with your coaching.)

Lesson Three

1. Review logging on/off, corrections using voice and keyboard.

2. Entering Numbers

   Dragon provides the numbers zero (spelled 0) through ninety-nine (spelled 99). It also has hundred (00), thousand (000) and million (000000) which can be added to make larger numbers. Try these:

63	Say "sixty-three". If the number does not appear, type "6". "63" should now appear.
4,328	Say "four", then "comma" and choose the comma in brackets. Say "three", then "twenty-eight".
24,000	Say "twenty-four", then "comma", then "thousand".
1985	Say "nineteen", then "eighty-five". Dragon automatically 'clings' to the left when you say the "eighty-five".
3.7	Say "three", then "point", then seven". Again, Dragon will automatically cling to the left when you say the "point".

3. There is a Speed-up Drill to train Dragon on numbers. Students may wish to do it quickly for practice.

Lesson Four

1. Review the two ways of making corrections (voice and keyboard).

2. Using the editing menu.

   Explain that there are three representations stored in the Dragon memory: the string of sounds, the word as it appears on the choice list (word name) and the keystrokes that get put on the screen. For example, "point", [.] and .

   To reach the editing menu:

   Say "voice console", then "edit". The following menu will appear:

   F FIND word
   K edit KEYSTROKES
   R REMOVE Keystrokes
   W edit WORD name
   P edit PUNCTUATION
   D DELETE word
   Q QUIT

   At the top of the screen the current word is displayed. To choose another word, select F. The word name or keystrokes can now be edited, removed or the whole word deleted. Punctuation can also be altered. Try the following examples to demonstrate:

   a. Say "mister". The choice menu will have Mr. as its first choice. Go to the edit menu. Change keystrokes to "Mister", as in the play, "Mister Roberts".

      Return to document, say "mister" and observe the result.

      Return again to the editor and change the word name as well to mister. Now return to the document and observe the result.

      Return to the edit menu and change the word name and the keystrokes back to the original setting.

   b. Say "dot". Go to the editing menu.

      Press k to edit the keystroke sequence.
      Type the '.', then [enter].
      Press p to set the punctuation. We want this to have no spaces around it so we select clings to left and clings to right for the punctuation definition.
      Press q to quit.

      Observe the result.

Lesson Five

1. Review any material about which the student may have questions.

2. Creating Macros

   A Macro can be created which will execute any set of keystrokes. Remind students that the macro will consist of three parts: a voice command, a word name as it will appear on the choice list and a set of keystrokes.
   Suppose you want a macro that will spell out the entire name of the university whenever you say the words "cee sun"

Voice command	"cee sun"
Word name	CSUN
Keystrokes	California State University at Northridge

   The following steps should be followed to accomplish this:

   a. Say the utterance "cee sun".
   b. Say "begin spell mode".
   c. Type in CSUN.
   d. Say "voice console".
   e. Say "edit." The editing menu will appear.
   f. Cursor to Option K, then [enter].
   g. Type in California State University at Northridge, then [enter].
   h. Type Q to quit editing.
   i. Say "ok" to accept the command.

3. Practice creating macros by programming in a few of the frequently-used command keys for WordPerfect using the above procedure such as Shift-F7 (print) and F10 (save).

   For example, the steps to make a macro that will execute the reveal codes (Alt-F3) are as follows:

   a. Say the utterance "reveal codes".
   b. Say "begin spell mode".
   c. Type in Alt-F3.
   d. Say "voice console".
   e. Say "edit." The editing menu will appear.
   f. Cursor to Option K, then [enter].
   g. Hold down the [alt] key and strike the [F3] key, then [enter].
   h. Cursor to P to change punctuation, then [enter].
   i. Cursor to L (clings left), then [enter].
   j. Type Q to quit punctuation, and Q again to quit editing.
   k. Say "ok" to accept the command.

   Now when the utterance "reveal codes" is spoken, Alt-F3 will appear in the choice list and the codes will actually be revealed. (To turn off the reveal codes, simply say, "reveal codes" again, which re-executes the command, turning off the reveal codes function.

Note that steps h, i and j must be executed. This is so that Dragon will not insert a space in the text each time "reveal codes" is activated. (Each time a word is spoken, a space is inserted before it by default by Dragon.)

Punctuation Practice

Dictate the following paragraphs to the Dragon for practice in giving punctuation commands:

"You have to work harder than everyone else."

"You have to know your strengths--and use them to the hilt."

"You have to learn to explain your problems [to] instructors."

"Most of all, you have to pick yourself up and start over again when you fail."

These words were spoken by a student with learning disabilities who graduated from Teacher's College despite the fact that he and his parents were told over and over again that he could not learn. Our book, Unlocking Potential, contains a wealth of information and ideas for prospective postsecondary students and their families.

Here are the command words you need to get the above paragraphs:

[new paragraph]
[tab key]
[open quote]
You have to work harder than everyone else
[period]
[close quote]
[new paragraph]
[tab key]
[open quote]
You have to know your strengths
[hyphen][hyphen]
and use them to the hilt
[period]
[close quote]

[new paragraph]
[tab key]
[open quote]
You have to learn to explain your problems

[open bracket] to [close bracket] instructors
[period]
[close quote]

[new paragraph]
[tab key]
[open quote]
Most of all
[comma]
you have to pick yourself up and start over again when you fail
[period]
[close quote]

[new paragraph]
[tab key]
These words were spoken by a student with learning disabilities who graduated from
[shift key] Teacher's
[shift key] College despite the fact that he and his parents were told over and over again that he could not learn
[period]
Our book
[comma]
[function-8]
[shift key] Unlocking [shift key] Potential
[function-8]
contains a wealth of information for prospective postsecondary students and their families
[period]

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